ABSTRACT

Title of Thesis:	ECOLOGICAL RESTORATION DRIVES FUNCTIONAL COMPOSITION AND DIVERSITY IN URBAN FOREST PATCHES
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Urbanization greatly alters environmental conditions, affecting biodiversity in cities and ecological processes. To restore processes and native biodiversity, land managers have turned to ecological restoration of urban forest patches. Urban forest patches, nested within urban ecosystems, are subject to urban influences during ecological succession.

Building on a long-term study evaluating outcomes of ecological restoration in New York City, I examined the effects of urban conditions, restoration, and forest succession on functional composition and diversity of restored and unrestored urban forest patches after 15-20 years. Functional traits play an essential role in community assemblages and influence the resilience and ecosystem functioning of urban ecosystems.

I found that restored plots had greater functional evenness. Differences in functional composition indicated direct influence from restoration, succession, urban

conditions, and success in meeting restoration goals. These results demonstrate that ecological restoration drives changes in functional composition and diversity of urban forest patches.

ECOLOGICAL RESTORATION DRIVES FUNCTIONAL COMPOSITION AND DIVERSITY IN URBAN FOREST PATCHES

by

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List of Abbreviations

NRG: Natural Resources Group

UFEP: Urban Forest and Education Program

UHI: Urban Heat Island

DBH: Diameter at Breast Height

CWM: Community Weighted Mean

IVI: Importance Value Index

SLA: Specific Leaf Area

FRic: Functional Richness

FEve: Functional Evenness

FDiv: Functional Divergence

1. Introduction

Cities have become home to over half of the world's population (United Nations, 2018), and the understanding of urban ecosystems, their processes, and ecosystem services should be at the forefront of urban planning and conservation (Pickett et al. 2011; Bolund and Hunhammar 1999). In these human dominated systems, the rapid movement of plants from around the world has created novel plant assemblages. These introductions, whether they are intentional or accidental, can become the source for invasive species that negatively impact native species regenerating in urban natural spaces, altering attributes like resource availability and species availability (Vitousek et al. 1997; Kowarik 1990; Čeplová, Lososová, and Kalusová 2017). When compared to their rural counterparts, urban city conditions include increased temperatures, resulting from the urban heat island effect (Alcoforado and Andrade 2008); highly heterogeneous soil (Pouyat et al. 2010); and higher rates of pollution and nitrogen deposition (Pouyat et al. 2010). Changes in buildings, infrastructure, and land use history at a fine spatial scale in cities have created highly heterogeneous landscapes (Pickett et al., 2011; Cadenasso et al., 2007; Johnson *et al.*, 2018). These changes have a multitude of effects on the assemblage of floral communities in cities as a whole (Kowarik 1990; Sukopp 2008; Bonthoux et al. 2019; Johnson, Borowy, and Swan 2018; Chocholoušková and Pyšek 2003; Lososová et al. 2006; Aronson et al. 2016).

Within the urban matrix, there exist habitat fragments that consist of naturally regenerating vegetation (Forman 2014; Gaston 2010; Sutton and Morgan 2009) where plant communities are assembled through urban filters (Sutton and Morgan 2009;

Godefroid and Koedam 2003). These habitat fragments have been noted as potential areas for species conservation in cities as well as areas at high risk for invasion from non-native species (Angold et al. 2006; Godefroid and Koedam 2003; Sutton and Morgan 2009; Vallet et al. 2010; Kowarik 2011). Forest patches in urban ecosystems have been a particular area of interest due the number of ecological benefits these habitats can provide (Bolund and Hunhammar 1999; Gaston 2010; Godefroid and Koedam 2003). Forests are essential components in the world's water, carbon, and nutrient cycles (Food and Agriculture Organization of the United Nations 2020). Urban forests also play a large role in human health and pollution mitigation (Grote et al. 2016; Escobedo, Kroeger, and Wagner 2011; Nowak, Crane, and Stevens 2006). While the urban forest consists of all trees in an urban area, including street trees and intentionally planted landscape trees (McPherson et al. 1997; Escobedo, Kroeger, and Wagner 2011), urban forest patches defined in this study are regenerating areas of remnant forest habitat located within the urban matrix (Johnson et al. 2020). Urban forest patches, in addition to benefits listed above, provide habitat for urban wildlife and have the potential to serve as a source for urban biodiversity (Forman 2014; Zipperer 2002; Honnay et al. 1999). Because of the numerous benefits provided by urban forest patches, it is necessary to understand their processes and responses to natural and man-made disturbances.

Ecological restoration can be seen as a designed disturbance and serve as a driver of change to vegetation dynamics and direct them towards a set of goals (Luken 1990; Pickett, Cadenasso, and Meiners 2009; Palmer, Ambrose, and Poff 2008). Restoration in urban ecosystems aims to restore ecosystem functions, biodiversity, and stability, much like restoration of their rural counterparts (Palmer 2004). Like any type of disturbance, these projects also drive the assemblage of plant communities in the targeted system (Fischer, von der Lippe, and Kowarik 2013). Understanding how restoration practices affect the filtering and assemblage of species is critical to predicting post restoration outcomes and management post restoration (D'Astous et al. 2013; Doherty, Callaway, and Zedler 2011).

In trying to explain and understand ecological processes acting upon a system, investigating functional traits in a community provides an insight into the processes driving community assemblages because species in a community are assembled by their functional traits (Williams et al. 2009; Morin 1999; Aronson et al. 2016). Functional traits have also been found to influence ecosystem functioning and processes in a community by altering carbon cycling (Dwyer, Hobbs, and Mayfield 2014; Lavorel and Garnier 2002; Cornelissen et al. 2003), biotic interactions (Sargent and Ackerly 2008; McCay, McCay, and Czajka 2009), and nutrient cycling (Meziane and Shipley 1999; Eviner and Chapin 2003; Laughlin 2014; Lavorel and Garnier 2002). Based on this, it has been noted that functional trait composition and diversity may explain ecosystem processes better than species richness and diversity (Díaz and Cabido 2001; Violle et al. 2007; Lavorel and Garnier 2002). Because of the impacts that functional traits have on ecosystem functions and processes and community assemblage, investigating functional composition and diversity may provide a better understanding of how urban conditions in conjunction with ecological restoration efforts, affect plant assemblages in urban forest patches.

1.1 Functional Traits

Functional traits, defined by Díaz and Cabido (2001) as "the characteristics of an organism that are considered relevant to its response to the environment and/or its effects on ecosystem functioning", play an essential role in community assemblages (Morin 1999; Williams et al. 2009; Díaz and Cabido 2001; Cornwell and Ackerly 2009; Lebrija-Trejos et al. 2010). According to community assembly theory, abiotic conditions and biotic interactions in a community act as filters for species establishment and persistence in the community (Morin 1999; Aronson et al. 2016; Williams et al. 2009). These environmental conditions filter species based on their functional traits (Morin 1999; Williams et al. 2009; Díaz and Cabido 2001; Cornwell and Ackerly 2009; Lebrija-Trejos et al. 2010).

Much like species composition and diversity, functional composition and functional diversity are used to understand and investigate ecosystem processes acting upon a system. Functional composition is defined as the presence and relative abundance of functional traits in a community (Diaz and Cabido, 2001), while functional diversity takes functional composition into account (Diaz and Cabido, 2001) and is divided into a number of functional diversity indices (Mason *et al.*, 2005; Villéger *et al.*, 2008). Functional richness is defined as the niche space occupied by species in a community, while functional evenness is how evenly filled the occupied niche space is (Mason et al. 2005). Functional richness provides an insight as to what resources are being utilized and which ones are unused in a community (Mason et al. 2005). Functional evenness on the other hand, can be interpreted as how well a resource is being used within a community where low functional evenness indicates underutilization of a resource and a potential niche that could be taken over by an invasive species (Mason et al. 2005). Lastly, functional divergence can be described as whether or not species exist at extreme values for a trait or niche space at high levels or if they congregate within a narrow range (Mason et al. 2005). High functional divergence indicates low resource competition and may mean communities have more efficient use of resources (Mason et al. 2005).

1.1.1 The Role of Functional Traits in Ecosystem Functioning in Urban Ecosystems

While it is known that biological diversity is essential to ecosystem functioning and processes (Díaz and Cabido 2001), it has also been shown that species' functional traits influence ecosystem functions and processes (Hooper et al. 2016; Laughlin 2014; Díaz and Cabido 2001; Funk et al. 2008; Eviner and Chapin 2003). Traits, such as pollination and seed dispersal, may affect biotic interactions between plants and wildlife (Taki et al. 2013; Sargent and Ackerly 2008; Laughlin 2014; Howe and Miriti 2004; McCay, McCay, and Czajka 2009) while leaf traits can have effects on carbon cycling (Dwyer, Hobbs, and Mayfield 2014; Laughlin 2014; Lavorel and Garnier 2002). Functional diversity plays a role in ecosystem functioning and stability, where it has been found that ecosystem processes are influenced by present functional traits and play roles in an ecosystem's response to disturbance (Díaz and Cabido 2001; Hooper et al. 2016; Cadotte, Carscadden, and Mirotchnick 2011; Zirbel et al. 2017). Functional traits possessed by a species also help scientists and land managers understand a species' resource requirements, tolerance to environmental conditions, and ultimately what ecological niches a species fills (Byun, de Blois, and Brisson 2018).

1.1.2 The Role of Functional Traits in Biological Invasions

Because humans now move organisms further and faster than historically possible, numerous purposeful or accidental species introductions have become the source for invasive species (Vitousek et al. 1997; Kowarik 1990; Čeplová, Lososová, and Kalusová 2017; Lockwood et al. 2013). Due to the number of negative impacts that invasive species have on native species populations and ecosystem processes and desire to prevent future species invasion, the use of species' functional traits has been used to predict species invasiveness in hopes of identifying potentially invasive species (Aronson, Handel, and Clemants 2007; Funk et al. 2008). Functional traits are also a potential tool to prevent invasion, where planting native species with functional traits similar to invasive species may prevent a community from being invaded by invasive species (Funk et al. 2008; Drenovsky et al. 2012; Oswalt et al. 2015).

Concepts such as biotic resistance, the limiting similarity hypothesis (Macarthur and Levins 1967) and the insurance effect hypothesis (Ives, Klug, and Gross 2000; Tilman et al. 1997; Yachi and Loreau 1999) used in invasion biology have ties to functional traits as they address how invasive species may interact and establish based on the number of filled ecological niches and number of species filling each niche (Byun, de Blois, and Brisson 2018; Lockwood et al. 2013; Drenovsky et al. 2012; Funk et al. 2008; Díaz and Cabido 2001). Multiple species possessing the same trait and filling in the same ecological niche is termed functional redundancy (Naeem and Li 1997; Wohl, Arora, and Gladstone 2004) and has the potential to be a useful strategy in preventing future invasions (Díaz and Cabido 2001; Walker 1992; Funk et al. 2008). The limiting similarity hypothesis suggests that land managers may be able to promote the growth of native species possessing traits similar to regionally invasive species to prevent such species from invading communities (Fargione, Brown, and Tilman 2003; Emery 2007; Turnbull et al. 2005; Fagúndez and Lema 2019; Laughlin 2014).

1.2 Conceptual Diagrams

To explore and visualize the drivers, and interactions between the drivers, influencing long term outcomes of ecological restoration in urban forest patches the following conceptual model was developed (see Figure 1). In this model, there are three main drivers: urban ecosystems, forest vegetation dynamics, and ecological restoration. These drivers interact with each other, ultimately driving long term outcomes of ecological restoration in urban forest patches.

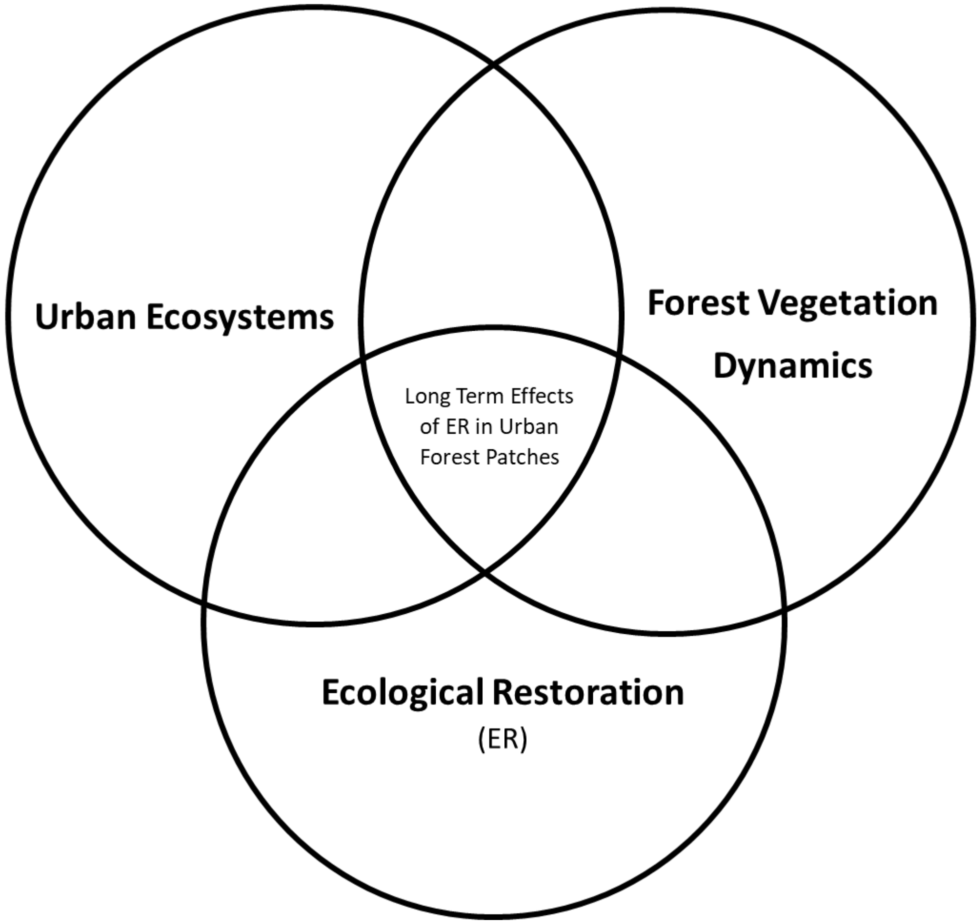

Figure 1. Conceptual diagram illustrating components of urban ecosystems, vegetation dynamics, and ecological restoration and their interactions. Interactions between the components are located where circles overlap. An example of this is that ecological restoration alters species availability by removing and/or adding species from a site. Diagram components and interactions (overlaps) and their effects on functional traits and functional diversity are described in sections below.

To visualize how these major concepts and their interactions affect each other directionally and to put them into the context of this study, this conceptual model (see Figure 2) was developed.

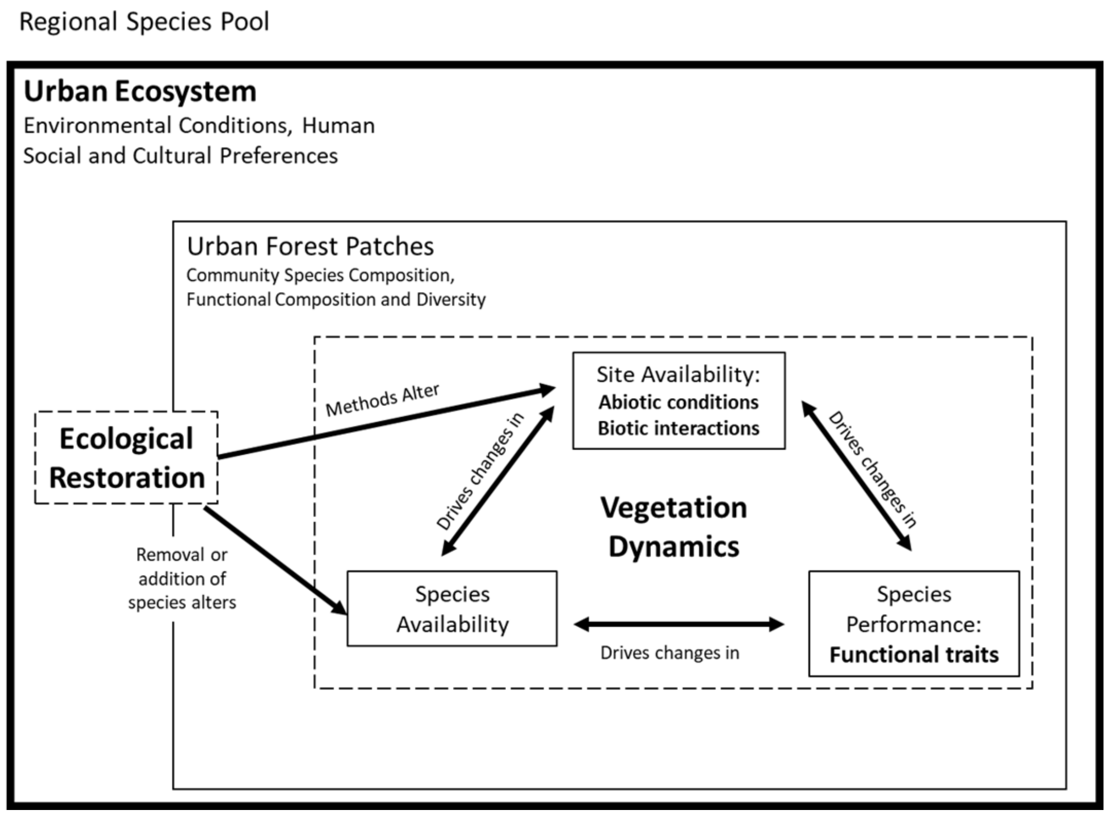

Figure 2. Nested conceptual model illustrating the directions of influence between urban ecosystems, ecological restoration, and vegetation dynamics. Nested boxes indicate a particular habitat within the larger urban ecosystem, in this case it is urban forest patches. Ecological restoration is boxed to emphasize that it is a major component of this study. Vegetation dynamics is also boxed to indicate that it is a major study component, but also to emphasize the many components nested within this larger concept occurring in urban forest patches. Arrows and text indicate the direction of influence and interaction between major components and their sub-components.

1.2.1 Urban Ecosystems

Changed abiotic and biotic interactions observed in cities serve as altered filters for urban community assemblage, selecting species with certain traits (Williams, Hahs, and Vesk 2015; Aronson et al. 2016). Such filters include altered environmental conditions, like increased temperatures (Hardin et al. 2018; Alcoforado and Andrade 2008) and increased soil pollution (Pouyat et al. 2010), and novel species assemblages (Williams, Hahs, and Vesk 2015; Kowarik 2011; McCay, McCay, and Czajka 2009). Filters also include social interactions, decisions, and policies attributing to the heterogeneous landscapes of urban ecosystems with changes in buildings, infrastructure, and land use history (Pickett et al. 2011; Cadenasso, Pickett, and Schwarz 2007; Johnson, Borowy, and Swan 2018).

1.2.1.1 Functional Trait Trends in Urban Ecosystems

Studies investigating trends in plant functional traits in the urban context have found that urban environments do indeed filter species based on their functional traits (see Table 1). Conditions of urban ecosystems filter species in favor of taller plants, heavier seeds, native species dispersed by wind or seed hoarding, non-native species spread by bird consumption (endo-zoochory), and species with an affinity for high light conditions (see Table 1). However, many of these studies used whole urban floras to inform these functional trait trends or studied specific urban areas such as vacant lots (Borowy and Swan 2020), residential landscapes (Kendal, Williams, and Williams 2012) and urban hardscapes (Frazee et al. 2019). For studies looking at remnant habitats, the focus has been primarily on riparian (e.g., Burton, Samuelson, and Mackenzie 2009; Brice, Pellerin, and Poulin 2017; Schwoertzig et al. 2016) and grassland (e.g., Fischer, von der Lippe, and Kowarik 2013; Williams et al. 2005; van der Walt et al. 2015) habitats. Studies focusing on trees and other woody species in urban areas have put emphasis on the urban forest (Grote et al. 2016), sometimes defined to consist of intentionally planted street trees and landscape trees in addition to naturally regenerating urban forest patches (McPherson et al. 1997). For naturally regeneration urban forest patches, little is known about their trends in functional composition and diversity.

Table 1. Functional trait trends in urban ecosystems. Trends in functional traits driven by conditions in urban ecosystems are indicated with arrows and are supported by literature listed. An upwards arrow indicates an increase in the abundance of individuals possessing listed trait, driven by urban conditions. A downwards arrow indicates a decrease in the abundance of individuals possessing listed trait.

Trait	**Driver**	**Trends**	**Citations**
Growth Form	Urban	↑ Trees; ↓ Graminoids	Williams, Hahs, and Vesk (2015); Dolan, Aronson, and Hipp (2017); Chocholoušková and Pyšek (2003)
Shade Tolerance	Urban	↑ Shade intolerance	Burton, Samuelson, and Mackenzie (2009); Williams, Hahs, and Vesk (2015)
Seed Mass	Urban	↑ Seed mass	Duncan et al. (2011); Thompson and McCarthy (2008); Williams, Hahs, and Vesk (2015)
SLA	Urban	Moderate SLA	(Knapp 2010; Williams, Hahs, and Vesk 2015)
Maximum Tree Height	Urban	↑ Height	Duncan et al. (2011); Thompson and McCarthy (2008); Williams, Hahs, and Vesk (2015)
Seed Dispersal	Urban	↑ Non-native endozoochoric species; ↑ Native wind dispersed and seed hoarded species	(Aronson, Handel, and Clemants 2007; Knapp 2010; Burton, Samuelson, and Mackenzie 2009; Williams, Hahs, and Vesk 2015; Dolan, Aronson, and Hipp 2017)
Pollination	Urban	↑ Biotic	(Aronson 2007; Dolan, Aronson, and Hipp 2017)
Tree Lifespan	Urban	↑ Longer lifespan	(Williams, Hahs, and Vesk 2015)

1.2.2 Forest Vegetation Dynamics

Studies investigating trends in plant ecology in the urban context have found that forests, and all ecosystems, undergo changes to community structure and species composition over time. This is referred to as ecological succession, or as vegetation dynamics. Historically, succession has been seen as unidirectional process starting from an herbaceous system and ending in a forested system (Clements 1916). More recently, succession has been conceptualized as a multidirectional process with a variety of community outcomes driven by changes in environment and species, termed vegetation dynamics (Pickett, Cadenasso, and Meiners 2009). The framework for vegetation dynamics is grounded in three major causes for changes in a community over time: site availability, species availability, and species performance (Pickett, Cadenasso, and Meiners 2009).

In forested systems, changes in site availability may change over time as closed tree canopies alter light conditions or from disturbances, such as fire, that open up available soil for species growth and regeneration (Turner and Romme 1994). Species available to a forested community can be altered as humans introduce new species (Chocholoušková and Pyšek 2003; Čeplová, Lososová, and Kalusová 2017; Pickett et al. 2011) and by the differences in the surrounding landscape (Duncan and Duncan 2000; Butaye et al. 2002; Harper and Macdonald 2002). Species performance is determined by a species' ability to persist and grow in the present environmental conditions (Pickett, Cadenasso, and Meiners 2009). Differences in species performance can be attributed to functional traits as they are the characteristics that allow a species to grow in its environment (Díaz and Cabido 2001; Morin 1999; Williams, Hahs, and Vesk 2015; Aronson et al. 2016).

1.2.2.1 Functional Traits in Forest Succession

Functional diversity and composition of an ecosystem changes as it undergoes ecological succession and favors species with certain traits (Muscarella et al. 2016; Swenson et al. 2012; Lohbeck et al. 2012; Raevel, Violle, and Munoz 2012). Early secondary succession in forests is characterized by high light conditions favoring traits such as shade intolerance (Reich et al. 1998; Glitzenstein, Harcombe, and Streng 1986; Canham et al. 1994) , lower seed mass (Fenner and Thompson 2005; Westoby et al. 2002; Falster and Westoby 2005), lower specific leaf area (SLA) (Lambers, Chapin, and Pons 1998; Poorter 1999; Dwyer, Hobbs, and Mayfield 2014), greater abundance of biotically pollinated species (Taki et al. 2013; Hanula, Ulyshen, and Horn 2016; Sargent and Ackerly 2008), and greater abundance of wind pollinated species (Finegan 1984; Körner 2005) (see Table 2 for more information). Over time, environmental conditions in a forest change to favor shade tolerance (Reich et al. 1998; Glitzenstein, Harcombe, and Streng 1986; Canham et al. 1994), larger seed mass (Fenner and Thompson 2005; Westoby et al. 2002; Falster and Westoby 2005), higher SLA (Lambers, Chapin, and Pons 1998), greater abundance of abiotically pollinated species (Taki et al. 2013; Hanula, Ulyshen, and Horn 2016; Sargent and Ackerly 2008), and greater abundance of species dispersed by seed hoarding (Finegan 1984; Körner 2005) (see Table 2 for more information). However, these are trends found in non-urban systems and thus do not reflect urban influences on community assemblage within urban forest patches.

Table 2. Functional trait trends driven by forest vegetation dynamics. Trends in functional traits driven by forest vegetation dynamics are indicated with arrows and are supported by literature listed. An upwards arrow indicates an increase in the abundance of individuals possessing listed trait, driven by forest vegetation dynamics. Horizontal arrows indicate a shift in abundance of species possessing listed trait over time.

Trait	**Driver**	**Trends**	**Citations**
Growth Form	Forest Vegetation Dynamics	↑ Trees over time	(Pérez-Harguindeguy et al. 2013)
Shade Tolerance	Forest Vegetation Dynamics	Intolerant → Tolerant	(Lienard, Florescu, and Strigul 2015; Flores, Gourlet-Fleury, and Picard 2006; Morin 1999; Glitzenstein, Harcombe, and Streng 1986; Finegan 1984; Bazzaz 1979)
Seed Mass	Forest Vegetation Dynamics	Lighter → Heavier	(Fenner and Thompson 2005; Westoby et al. 2002; Falster and Westoby 2005)
SLA	Forest Vegetation Dynamics	Smaller → Larger	(Dwyer, Hobbs, and Mayfield 2014; Poorter 1999; Lambers, Chapin, and Pons 1998)
Maximum Tree Height	Forest Vegetation Dynamics	Shorter → Taller	(Lambers, Chapin, and Pons 1998)
Seed Dispersal	Forest Vegetation Dynamics	Wind → Seed Hoarding	(Lohbeck et al. 2015; Dzwonko and Loster 1992; Finegan 1984; Körner 2005)
Pollination	Forest Vegetation Dynamics	Biotic → Abiotic	(Taki et al. 2013; Körner 2005; Skov 2000; Finegan 1984; Hanula, Ulyshen, and Horn 2016; Sargent and Ackerly 2008)
Tree Lifespan	Forest Vegetation Dynamics	Shorter → Longer	(Finegan 1984; Körner 2005)

1.2.3 Ecological Restoration

Ecological restoration in urban ecosystems is important because urban ecosystems are altered and driven by human activity (Yokohari and Amati 2005; Ingram 2008; Purcell, Friedrich, and Resh 2002; Clarkson and Kirby 2016; Violin et al. 2011; Miller and Hobbs 2002; Miyawaki 1998; Bounds et al. 2014). Ecological restoration is a process or set of methods aimed to restore ecosystem benefits, functions, and processes to a degraded or disturbed system (McDonald et al. 2016). Restoration methods and ecosystem processes alter abiotic and/ or biotic filters (Funk et al. 2008; Funk and McDaniel 2010), setting the ecosystem towards a different successional trajectory (Luken 1990; Palmer, Ambrose, and Poff 2008; Aerts and Honnay 2011). Ecological restoration often includes a set of goals and restoration methods are employed to meet identified goals (Gann et al. 2019; Purcell, Friedrich, and Resh 2002).

In many cases, ecological restoration alters abiotic conditions that serve as filters for community assembly (Funk et al. 2008; Gondard et al. 2003; Hedberg et al. 2013; Hérault, Honnay, and Thoen 2005). Doing so is another way to exclude the growth and establishment of invasive species is to alter abiotic conditions found within a community (Byun, de Blois, and Brisson 2018; Funk and McDaniel 2010). While altering abiotic conditions and biotic interactions is key to ecological restoration, the analysis of functional diversity and functional composition post-ecological restoration as a measure of success has not been commonly performed (Hérault, Honnay, and Thoen 2005; Tullos et al. 2009; Hedberg et al. 2013).

Unlike their rural counterparts, restoration in urban ecosystems needs to consider that trajectories may differ from historical reference points due to the changes in land use (Cadenasso, Pickett, and Schwarz 2007; Hobbs et al. 2006), social and cultural preferences (Pickett et al. 2011; Kendal, Williams, and Williams 2012; Kowarik 2011), soil conditions (Pouyat et al. 2010; Lovett et al. 2000; Pouyat, McDonnell, and Pickett 1997), temperature (Alcoforado and Andrade 2008; Hardin et al. 2018), and species interactions (Hobbs, Higgs, and Harris 2009) that take place over time in urban ecosystems. This means successional trajectories of urban forest patches may not be the same as rural forests. Though restoration projects have been conducted in urban and rural habitats, there have not been many studies investigating long term outcomes of ecological restoration due to how young the field of ecological restoration is (Wortley, Hero, and Howes 2013).

1.2.3.1 Functional Trait Trends in Ecological Restoration

Functional traits have become a potential tool in preventing future species invasion (Funk et al. 2008; Drenovsky et al. 2012) and a potential tool for ecological restoration (Funk et al. 2008; Drenovsky et al. 2012; Pywell et al. 2003; Sandel, Corbin, and Krupa 2011). Some studies have utilized a target suite of functional traits as a goal to identify restoration methods that lead to communities with the identified target set of functional traits (Laughlin 2014; Hérault, Honnay, and Thoen 2005). Others attempt to characterize a suite of traits that would lead to successful species establishment post-restoration (Fischer, von der Lippe, and Kowarik 2013; Pywell et al. 2003). From these studies, it can be seen that changes to the abiotic environment and biotic interactions from ecological restoration affect the functional traits present in a community (Doherty, Callaway, and Zedler 2011; Engst et al. 2016; D'Astous et al. 2013; Hedberg et al. 2013; Hérault, Honnay, and Thoen 2005) and methods used in restoration can create different outcomes in functional composition (Laughlin 2014; Hérault, Honnay, and Thoen 2005).

Studies investigating trends in functional compositions and functional diversity post-restoration have occurred in natural grasslands (Engst et al. 2016) and wetlands (Doherty, Callaway, and Zedler 2011; D'Astous et al. 2013; Hedberg et al. 2013). However, few studies investigate functional composition and functional diversity, post-restoration, in urban remnant habitats (Zirbel et al. 2017). To investigate how interactions between urban conditions, vegetation dynamics, and ecological restoration drive trends in functional traits, I examine the functional composition and functional diversity of urban forest patches in New York City parks 15-20 years after the initiation ecological restoration.

1.3 Study System

To investigate long term outcomes of ecological restoration in urban forest patches, the study needs to take place in a city where ecological restoration has been initiated in the city's urban forest patches. In New York City, there exist urban forest patches within city parks managed by the New York City Department of Parks and Recreation. Ecological restoration projects in these urban forest patches have been implemented by the Natural Resources Group. Because New York City is an urban ecosystem with ecological restoration implemented in its urban forest patches, this makes it an ideal system to investigate the impacts of urban conditions, forest vegetation dynamics, and ecological restoration on long term outcomes of ecological restoration in urban forest patches.

Previous studies by Johnson and Handel (2016 and 2019) have laid down the foundation by investigating long term effects of ecological restoration and management on species composition and forest structure in these urban forest patches. This study builds on these previous studies and examines long term effects of ecological restoration on functional traits in the same urban forest patches.

1.3.1 New York City

New York City (40.7128° N, 74.0060° W) is a large metropolis located at the southeastern corner of New York state, bordering the state of New Jersey. The city covers 302.6 square miles (US Census Bureau, 2019). Population in New York City was estimated to be 8.3 million people as of July 2019 (U.S. Census Bureau 2019) with a population density of 27,012.5 per square mile (US Census Bureau, 2019). Bodies of water surrounding the city include the Atlantic Ocean, Hudson River, and Long Island Sound. The larger New York metropolitan area has an estimated population of 19.9 million people according the 2018 American Community Survey (U.S. Census Bureau 2018). It is the largest metropolitan area in the United States and is comprised of areas in New Jersey, Pennsylvania, and New York (US Census Bureau, 2018).

The climate of New York City is characterized by cold winters and warm, humid summers. Under the Köppen-Geiger climate classifications, New York City is a Cfa, or humid subtropical climate. It is also subject to urban heat island effect such as increased average and nighttime temperatures and reduced wind speeds (Hardin et al. 2018; Gedzelman et al. 2003). Average annual air temperatures (between 1981 and 2010) are 12.7˚C. Summer temperatures (June 1-August 31) average at 23.6˚C and winter temperatures (December 1 – February 28) average at 1.7˚C. Average precipitation (between 1981 and 2010) is 126.8 cm annually and is evenly spread out through the year. Average annual snowfall is 63.7 cm with the most snowfall occurring in January and February.

Since 1990, summer temperatures in New York City have an increasing trend of 0.1˚C every decade in Central Park, 0.3˚C at John F. Kennedy Airport, and 0.4˚C at LaGuardia Airport (González et al. 2019). Winters have also been getting warmer in New York City as the number of days below freezing (0˚C) has had a decreasing trend of 1.9 days per decade between 1990 and 2017 (González et al. 2019). Between the years of 1900 and 2013, there has been an increase in 2 cm of precipitation every decade (Horton et al. 2015). Between 2010 and 2019, precipitation averaged at 128.9 cm annually and snowfall averaged at 93.7 cm annually.

Original topographical features of New York City and adjacent areas were shaped by the Wisconsin Ice Sheet. The terminal moraines left behind from this glacial period, known as the Ronkonkoma and Harbor Hill moraines, form much of Staten Island and Long Island’s backbone, where the boroughs of Brooklyn and Queens are located. Also left behind were the large boulders that can be found throughout the city. Manhattan and the Bronx sit upon 4 different bedrock formations that serve as the foundation for skyscrapers throughout these boroughs. Today the city is primarily covered in impervious surfaces, like pavement and buildings. There are 37 different soil series in the city (Huot *et al*., 2017) that highlight the heterogeneous nature of urban areas (Pouyat et al. 2010).

Plant life in New York City consists of approximately 2177 species (DeCandido, Muir, and Gargiullo 2004), 2029 of which are spontaneous (Atha et al. 2018), and contains 56.8% of New York State's plant species ever recorded. Currently, 37.7% of the city's overall flora and 33% of its spontaneous flora consist of non-native species (Atha et al. 2018). Of the 1357 native species historically recorded in New York City, 779 species persist (DeCandido, Muir, and Gargiullo 2004). New York City has lost 46.4% of its native herbaceous flora and 22.9% of its woody native flora since the mid-19th century (DeCandido, Muir, and Gargiullo 2004).

Forests are an important habitat found throughout the city, making up 5.5% of the city's land area (Pregitzer *et al*., 2019). Prior to European settlement, the regional forests were dominated by oaks (*Quercus spp.*), chestnuts (*Castanea dentata)*, ashes (*Fraxinus spp.*), sweet gum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), cherries (*Prunus spp.*), maples (*Acer spp.*), and hickories (*Carya spp.*) (Loeb 1987; Sisinni and Emmerich 1995). The loss of *Castanea dentata* in present forests was caused by chestnut blight (Greller 1972), a fungal disease introduced in the early 1900's that wiped out the majority of mature *C. dentata* trees in the Eastern United States. Being bordered by bodies of fresh water and salt water, New York City is also home to salt and freshwater marshes and meadows (Bounds et al. 2014). Presently, oak-hickory forests are one of the most common forest type in New York City and are native to the surrounding region (Pregitzer et al. 2019). These forests are typically dominated by oak species like *Quercus alba*, *Quercus rubra*, and/or *Quercus velutina* and hickory species like *Carya glabra*, *Carya ovata*, *Carya cordiformis*, and *Carya tomentosa* (Menard and Drake 2015).

1.3.2 Ecological Restoration in NYC Parks

New York City has over 29,000 acres (11,700 ha) of parkland, about 14% of the city's land, under the jurisdiction of the New York Department of Parks and Recreation (NYC Parks). An additional 3863 ha of parkland in New York City is owned by the federal government, New York State Department of Environmental Conservation, and New York State Parks (DeCandido, Muir, and Gargiullo 2004). In total, 17% (14,175 ha) of New York City's land consists of parkland. Of this parkland, 10,000 acres (around 4,046 ha) are comprised of forests, woodlands, meadows, and fresh and saltwater marshes managed by NYC Parks (NRG 2020).

In 1984, the Natural Resources Group (NRG) was created as part of NYC Parks with the purpose "to conserve New York City's natural resources for the benefit of ecosystem and public health through acquisition, management, restoration, and advocacy using a scientifically supported and sustainable research" (NRG 2020; Bounds et al. 2014). The group conducts ecological restoration projects and ecological assessments in New York City parks in addition to creating guidelines for urban habitat restoration (NRG 2020).

Mapping of New York City's natural areas in the 1980's identified high-quality natural areas, as well as degraded natural areas (Bounds et al. 2014; Johnson and Handel 2016). High-quality habitats recorded at this time are now a number of the Forever Wild Nature Preserves found throughout the 5 boroughs (Bounds et al.

2014). These findings also led the NRG to conduct ecological restoration projects in identified degraded areas (Bounds et al. 2014). Projects took place in forested habitats as well as wetland and other habitats found across the city (Bounds et al. 2014).

In New York City's forested habitats, ecological restoration was started by the Natural Resources Group in 1985 (Johnson and Handel 2016). The NRG then received funding in 1991 to start the Urban Forest and Education Program (UFEP) (Bounds et al. 2014). Restoration efforts were then carried out by the NRG under UFEP between 1991 and 1996 (Bounds et al. 2014; Johnson and Handel 2016). During the implementation of these ecological restoration project, over 150,000 trees were planted on 8000 acres of New York City parkland (Bounds et al. 2014). Parks that had forest patches restored during this time were located in all 5 boroughs. Ecological restoration goals were to remove target invasive species, restore the forest structure to resemble regional forests, and increase the regeneration of native tree species (Bounds et al. 2014).

1.3.3 Foundational Research: Johnson Restoration and Long-Term Urban Forest Change Study

To investigate the long-term effects of ecological restoration efforts performed by the NYC Parks' Natural Resources Group (NRG), Johnson and Handel (2016, 2019) performed a series of studies that are the foundation for this study. Previous studies studied the species composition and forest structure of restored sites 15-20 years after ecological restoration to sites that were invaded but not restored over the same period (Johnson and Handel 2016) and the effects of restoration treatment and management intensity and frequency on restoration outcomes (Johnson and Handel 2019). Building upon these studies, this study investigates long term outcomes of ecological restoration on functional trait composition and diversity in urban forest patches.

1.4 Questions and Hypotheses

To investigate long term outcomes of ecological restoration on functional trait composition and diversity in urban forest patches, I asked: does ecological restoration drive changes in functional composition and functional diversity? Ecological restoration is a process that alters abiotic conditions by restoration methods used (Funk and McDaniel 2010; Funk et al. 2008; M. A. Palmer, Ambrose, and Poff 2008). Restoration also alters abiotic conditions because of alterations in successional trajectory (Luken 1990). Biotic interactions are altered as species introductions and removals create novel communities (Kowarik 2011; Hobbs et al. 2006; Hobbs, Higgs, and Harris 2009). Changes in abiotic conditions and biotic interactions can be seen as changes to environmental filters driving community assemblages based on species' functional traits (Morin 1999; Williams et al. 2009; Aronson et al. 2016). By altering environmental drivers, there are also alterations in the functional traits found in a community (Aronson et al. 2016; Williams et al. 2009). Because ecological restoration drives changes in environmental filters driving functional traits in a community, I hypothesized that ecological restoration drives changes in functional composition and diversity in urban forest patches.

The following table (see Table 3) and hypotheses reflect my expectations of how urban ecology, vegetation dynamics, and ecological restoration come together and drive long term outcomes of functional composition and diversity in urban forest patches. Direct goals of ecological restoration included the removal of target invasive shrub and vine species and the planting of trees (Bounds et al. 2014). Restoration methods used to meet these goals will drive changes in growth form. Ecological restoration also aimed to restore the native forest structure (Bounds et al. 2014). In aiming to restored the native forest structure, ecological restoration also altered the successional trajectory of urban forest patches. This alteration in forest succession will drive differences in the composition of seed dispersal modes, pollination syndrome, seed mass, maximum tree height, and tree lifespan. These processes are occurring in urban forest patches and are influenced by conditions in the urban ecosystem. Urban conditions influencing these urban forest patches and ecological restoration outcomes will drive changes in seed dispersal mode and pollination syndrome. Detailed hypotheses regarding individual functional traits in different forest strata are outlined in Table 3 and described in the following sections.

Table 3. Hypotheses regarding the influences of urban ecology, vegetation dynamics, and ecological restoration driving trends in functional trait composition and diversity. Arrows indicate trends in functional trait composition and functional diversity index in restored urban forest patches compared to urban forest patches with no ecological restoration work. A dash indicates no difference between restored and unrestored patches. For example, an upwards arrow indicates that I expect the relative abundance of species with this trait to be

greater in restored urban forest patches than in unrestored urban forest patches. Forest strata are called out if I expect a particular trend to occur in that stratum and not in others.

Trait/Diversity Index	**Hypotheses**	**Forest Strata**
Growth form	↑ in Trees	Woody Understory and Ground Layer
	↓ in Shrubs and Vines	Woody Understory and Ground Layer
Shade Tolerance	↑ Shade tolerance	Understory
	–	Trees and Ground Layers
Seed Mass	↑ Larger	Woody Understory
	–	Trees and Ground Layer
SLA	↑ Larger	Woody Understory
	–	Trees and Ground Layer
Maximum Tree Height	↑ Larger	Trees and Woody Understory
	–	Ground Layer
Seed Dispersal	↑ Hoarding	Trees
	↑ Wind and Hoarding	Woody Understory and Ground Layer
	↓ Endo-zoochory	Woody Understory and Ground Layer
Pollination	–	Trees
	↑ Abiotic	Woody Understory and Ground Layer
Lifespan	↑ Long and moderate	Woody Understory and Ground Layer
	–	Trees
Functional Richness	–	All
Functional Evenness	↑	All
Functional Divergence	↓	All

1.4.1 Growth Form

Restoration efforts, in addition to trends in present urban floras, should result in restored plots having greater proportions of trees and less of shrub and vine growth forms in all forest layers. Compared to historic urban floras, present urban floras have increased woody species, specifically trees and shrubs due to tree planting in parks and escape of non-native shrubs (Williams, Hahs, and Vesk 2015; Dolan, Aronson, and Hipp 2017; Chocholoušková and Pyšek 2003; Knapp 2010). Ecological restoration conducted in this study system had specific goals to increase the regeneration of native trees and decrease the abundance of target invasive species via removal of these species, which were of the shrub and vine growth forms (Bounds et al. 2014; Johnson and Handel 2016).

1.4.2 Shade Tolerance

Restored and unrestored plots should have similar relative abundances of tree species with shade tolerance, intermediate shade tolerance, and shade intolerance. Trees in unrestored plots were subject to high light conditions above the shrub layer, which should promote the growth of shade intolerant species (Glitzenstein, Harcombe, and Streng 1986; Canham et al. 1994; Reich et al. 1998). The removal of dense shrub and vine cover in restored plots (Bounds et al. 2014) increased levels of light in these plots at the time of restoration. Because high light levels were present in restored plots at the time of restoration there should also be the growth and regeneration of shade intolerant trees. Trees in restored and unrestored plots were subjected to similar light levels, and should have similar abundances of shade tolerant, intermediate shade tolerant, and shade intolerant species.

Similar shaded conditions occurred in the ground layer in restored and unrestored plots, there should be similar cover by shade tolerant species in both plots. Ground layers in forests tend to have lower light levels, promoting the growth of shade tolerant species (Glitzenstein, Harcombe, and Streng 1986; Canham et al. 1994; Reich et al. 1998). In unrestored plots, dense layers of invasive shrubs and vines in the understory covered the ground layer (Johnson and Handel 2016; Bounds et al. 2014) casting deep shade. This deep shade should promote the growth and regeneration of shade tolerant species. To prevent the growth and regeneration of target invasive species, ecological restoration aimed to create a closed forest canopy and exclude invasive species by casting shade (Bounds et al. 2014). If successful, shade from the closed canopy should also promote the growth and regeneration of shade tolerant species.

If restoration was successful in closing the canopy, lower light conditions should be present in the understory promoting the growth of shade tolerant species. In the woody understory, restored plots should have more stems of shade tolerant species than unrestored plots. Unrestored plots were dominated by target invasive species that prevented the tree canopy from closing (Bounds et al. 2014), creating high light conditions in the understory. Lower light conditions, similar to later successional stages, favor the growth of shade tolerant species (Glitzenstein, Harcombe, and Streng 1986; Canham et al. 1994; Reich et al. 1998; Hewitt 1998).

1.4.3 Seed Mass

Because restored and unrestored plots have tree growth in similar light levels, restored and unrestored plots should have tree communities with similar average seed masses. High light conditions promote the growth of smaller seeded species while lower light levels promote the growth of larger seeded species (Fenner and Thompson 2005; Westoby et al. 2002; Pérez-Harguindeguy et al. 2013; Falster and Westoby 2005; Wilfahrt, Collins, and White 2014; Hewitt 1998). Tree regeneration was suppressed from the dense understory in unrestored plots (Bounds et al. 2014), creating high light conditions in the canopy. Similarly, removal of target invasive species during restoration created high light levels that planted and regenerating trees grew in. These high light levels are also a characteristic of early successional stages that favor species with smaller seed mass (Körner 2005).

Average seed mass in the woody understory and ground layer communities should be greater in restored plots. If restoration was successful in closing the forest canopy, understories and ground layers of restored plots have regenerated under lower light conditions. Low light levels favor species with larger seed mass (Fenner and Thompson 2005; Westoby et al. 2002; Falster and Westoby 2005; Hewitt 1998; Wilfahrt, Collins, and White 2014). On the other hand, unrestored plots had understories with high light conditions (Johnson and Handel 2016). High light conditions would promote the growth of smaller seeded species (Fenner and Thompson 2005; Westoby et al. 2002; Pérez-Harguindeguy et al. 2013; Falster and Westoby 2005; Wilfahrt, Collins, and White 2014; Hewitt 1998). This would lead to woody understory communities with lower average seed mass. Ground layer communities in unrestored plots should have average seed masses similar to the ground layer communities in restored plots. The ground layer in unrestored plots has low light conditions, similar to restored plots, but caused by a dense understory. These low light levels would favor species with larger seed mass (Fenner and Thompson 2005; Westoby et al. 2002; Falster and Westoby 2005; Hewitt 1998; Wilfahrt, Collins, and White 2014).

1.4.4 Specific Leaf Area

Restored and unrestored plots should have tree communities with similar average SLA values. If removal of target invasive species during ecological restoration increased light conditions where newly planted trees and regenerating trees occurred at the time of restoration, these higher light conditions would be similar to open vinelands in unrestored plots. Light conditions influence SLA (Lambers, Chapin, and Pons 1998; Westoby, Warton, and Reich 1999) and similar light levels should promote the growth of species with similar SLA values.

There should also be similar average SLA values between the ground layer communities in restored and unrestored plots. If forest canopies were closed in restored plots, this would create low light conditions in the ground layer. Similarly, in unrestored plots, the dense understory created a low light condition in the ground layer. Low light levels created by shade from closed canopies in restored plots and dense understory in unrestored plots would favor species with larger average SLA (Lambers, Chapin, and Pons 1998; Westoby, Warton, and Reich 1999). With similar light conditions occurring in the ground layers of restored and unrestored plots, the average SLA for ground layer communities in restored and unrestored plots should be similar.

In contrast, woody understory communities of restored plots should have greater average SLA than unrestored plots. Lower light levels favor species with larger SLA (Lambers, Chapin, and Pons 1998; Westoby, Warton, and Reich 1999). The closed canopy in restored plots would create shaded understories, promoting the growth of species with larger SLA.

1.4.5 Maximum Tree Height

Trees in restored plots should have greater average maximum tree heights. High light conditions present in the canopy of unrestored plots, and as trees in restored plots were growing, are similar to early forest succession where shorter tree species are more dominant (Lambers, Chapin, and Pons 1998; Finegan 1984; Peña-Claros 2003). However, the trees of restored plots also contain species that were purposefully planted during restoration (Johnson and Handel 2016; Bounds et al. 2014) altering tree species. These species tended to be later successional species, like oaks, which tend to be taller (Finegan 1984; Peña-Claros 2003; Körner 2005).

Similarly, the woody understory in restored plots should have greater average maximum tree heights. Saplings of tree species in the woody understory of unrestored plots were subject to high light levels once they grew past the shrub layer. High light levels in unrestored plot understories would favor shorter, early successional species (Finegan 1984; Lambers, Chapin, and Pons 1998; Peña-Claros 2003; Körner 2005). Ecological restoration also aims to redirect ecological succession on a trajectory similar to historic forests (McDonald et al. 2016). In the case of oak-hickory forests found in New York City and the surrounding region, this would lead to taller trees regenerating in the understory (Finegan 1984).

Seedlings of tree species in the ground layer should have similar average maximum tree heights. Because both ground layers have low light conditions, tree regenerating in this layer are growing in these conditions. Low light levels that simulate the lower light levels in later forest successional stages tend to favor taller tree species (Finegan 1984; Lambers, Chapin, and Pons 1998; Peña-Claros 2003).

1.4.6 Seed Dispersal

Dense shrub and vine cover created an open environment in unrestored plots (Bounds et al. 2014). Similarly, the removal of target invasive species in restored plots created open forest conditions at the time of restoration. In these open conditions, individuals that are smaller seeded and are easier to disperse by wind (Körner 2005). Open forest conditions are also a characteristic of early successional forests where tree species tend to be wind dispersed (Finegan 1984; Körner 2005). Based on this, I expect the abundance of tree with wind dispersal to be similar. Ecological restoration acts as a disturbance and can be seen as a reset in succession (Luken 1990) and created high light levels similar to early succession where wind dispersal in trees is favored (Finegan 1984; Körner 2005). However, a number of native trees were also planted during ecological restoration, many of which were oak species (Johnson and Handel 2016; Bounds et al. 2014) which are dispersed by hoarding. These planting would drive a greater abundance of trees dispersed by seed hoarding in restored plots.

Johnson and Handel (2016) found that native tree regeneration and abundance was greater in restored plots, which indicated success in reaching the ecological restoration goal to restore the native forest structure. In urban areas, successful native plants are tree species dispersed by wind or seed hoarding (Aronson 2007). The influence from urban conditions and ecological restoration methods would make wind and seed hoarding dispersal modes more abundant in the understory of restored plots. On the other hand, unrestored plot understories are dominated by invasive shrub and vine species that are dispersed by endo-zoochory, a trait that successful non-native shrubs and vines possess (Aronson 2007). Because unrestored plots had understories dominated by target non-native species while restored plot understories were not (Johnson and Handel 2016), unrestored plots should have more stems of endo-zoochoric species.

Ground layers in restored plots should have a greater relative abundance of species with wind dispersal and seed hoarding than unrestored plots. In restored plots, tree seedlings in the ground layer would have generated in low light conditions similar to later successional stages that favor trees dispersed by hoarding (Körner 2005; Finegan 1984). The restoration also created more open soil in the ground layer and had less ground cover in restored plots (Johnson and Handel 2016), creating more space for wind dispersed seed to land and germinate. A greater abundance of native tree cover in the ground layer (Johnson and Handel 2016) should lead to an increase in cover by species with wind dispersal and dispersal by hoarding since successful native plants in urban areas tend to be trees dispersed by these methods (Aronson, Handel, and Clemants 2007). Non-native invasive shrub and vine species in unrestored plots tend to have endo-zoochory as their mode of dispersal (Aronson 2007). Target invasive shrub and vine species were removed during ecological restoration (Bounds et al. 2014) and should lead to restored plots having a lower relative abundance of species with endozoochory.

1.4.7 Pollination Syndrome

The canopy of unrestored plots has high levels of light and is an open canopy due to the dominance of target invasive species that mimic early succession, providing habitat for pollinators (Taki et al. 2013; Sargent and Ackerly 2008) and select for biotically pollinated species. In restored plots, restoration created an open environment with high light levels, also mimicking early succession. Restored and unrestored plots should have a similar relative abundance of trees with abiotic and biotic pollination.

If ecological restoration was successful, there should be greater regeneration in native trees in the understory and ground layers of restored plots (Bounds et al. 2014). In this region, many trees are abiotically pollinated (Regal 1982; Mabry, Ackerly, and Gerhardt 2000; Willmer 2017). A goal of restoration was to restore the native forest structure, which includes a closed canopy (Bounds et al. 2014) and some of the restored plots were found have these closed canopies (Johnson and Handel 2016). Closed canopies lack the ability to support biotic pollinators (Taki et al. 2013; Sargent and Ackerly 2008; Hanula, Ulyshen, and Horn 2016), creating conditions favoring wind pollination. Pollination has also been shown to differ between successful species in urban areas with successful native flora characterized by wind pollination (a type of abiotic pollination) and non-native flora characterized by insect pollination (a type of biotic pollination) (Aronson 2007). Since unrestored plots are dominated by target invasive species in the understory and ground layers (Johnson and Handel 2016), biotic pollination is expected to be greater in unrestored plots than in restored plots. Because restored plots had greater abundances in native species (Johnson and Handel 2016), there should be a greater abundance of species with abiotic pollination in restored plots.

1.4.8 Tree Lifespan

Restored and unrestored plots should have trees with similar relative abundances of long, moderate, and short lifespans, favoring short lifespan. The high light conditions after restoration mimic light conditions of early succession, which favor pioneer species with short lifespans and less shade tolerance (Körner 2005; Finegan 1984). Similarly, unrestored plots are dominated by target invasive species and have little tree regeneration (Bounds et al. 2014; Johnson and Handel 2016) creating high light levels and an open environment similar to early succession. Trees in early succession tend to have shorter lifespans than those in later successional stages (Pérez-Harguindeguy et al. 2013; Fenner and Thompson 2005; Körner 2005; Finegan 1984).

In restored plots, saplings of tree species in the understory and seedlings of tree species in the ground layer with long lifespan should have greater relative abundance. Lower light conditions in the woody understory and ground layers post restoration mimic light conditions of later successional stages, which favor tree species with longer lifespans (Körner 2005; Finegan 1984). Tree species in later successional stages tend to have longer lifespans than those in earlier successional stages (Pérez-Harguindeguy et al., 2013; Fenner and Thompson, 2005; Finegan, 1984). In comparison, unrestored plots were noted to have primarily early successional tree species when trees were present (Johnson and Handel 2016). Because early successional trees tend to have shorter lifespans (Pérez-Harguindeguy et al. 2013; Fenner and Thompson 2005; Körner 2005; Finegan 1984), unrestored plots should have less a lower abundance of long lived trees and have a greater abundance of shorter lived trees.

1.4.9 Functional Richness

Functional richness is somewhat related to species richness (Villéger, Mason, and Mouillot 2008). Johnson and Handel (2016) found that while there was greater tree regeneration, the species richness and diversity present in restored and unrestored plots were not different (Johnson and Handel 2016). Functional richness tends to decrease with stand age (Bhaskar, Dawson, and Balvanera 2014), however both restored and unrestored plots had characteristics of early secondary forests with high light levels and later successional stages with low light levels. These similar conditions and similar species richness should cause similar levels in functional richness between restored and unrestored plots.

1.4.10 Functional Evenness

Functional evenness in restored plots should be greater than unrestored plots in all layers. Functional evenness is a functional diversity indices affected by species abundance (Villéger, Mason, and Mouillot 2008; Mason et al. 2005). Unrestored plots were dominated by a handful of species, many of which were target invasive species for ecological restoration (Johnson and Handel 2016; Bounds et al. 2014). Restored plots had these species removed during restoration and were then dominated by a greater number of species (Johnson and Handel 2016). Unrestored plots are dominated by a few species while restored plots have a greater number of dominant species, indicating that restored plots should have greater functional evenness than unrestored plots.

1.4.11 Functional Divergence

Similar to functional evenness, functional divergence in restored plots should be greater than unrestored plots in all layers. Functional divergence is another functional index changed by species abundance (Villéger, Mason, and Mouillot 2008). In unrestored plots, few target invasive species were dominant in the woody understory and ground layer (Johnson and Handel 2016). Restored plots were instead dominated by a greater number of species (Johnson and Handel 2016). Because few species dominated unrestored plots, it is expected for functional divergence to be low as many of the individuals would be of the same species and have the same traits.

2. Methods

To test my hypotheses, I used species abundance data from Johnson and Handel's (2016) vegetation sampling and standardized functional trait data to calculate functional composition and functional diversity indices for the different forest layers in restored and unrestored plots.

2.1 Trait Data

Functional traits selected in a study need to be considered carefully to reflect important aspects in the communities of interest and what is being compared (Kraft and Ackerly 2010; Weiher et al. 1999; Pérez-Harguindeguy et al. 2013; Zhu et al. 2017). In this study, traits of interest are those expected to change in response to urban conditions, forest vegetation dynamics, and conditions changed during ecological restoration. Because this study compares restored urban forest patches to unrestored patches dominated by invasive species, traits associated with potentially invasive non-native species in comparison to successful native species, whose distribution has increased in urban areas, also needed to be considered.

2.1.1 Trait Selection

Traits were selected based on their relevance to conditions in urban ecosystems, forest vegetation dynamics and ecological restoration. Ecological restoration alters vegetation dynamics and has been referred to as a way to reset ecological succession (Luken 1990). Traits reflecting such changes need to be considered. Seed mass (mg), tree height, and lifespan were selected because these traits increase as succession progresses (Körner 2005; Finegan 1984; Wilfahrt, Collins, and White 2014). Seed dispersal and pollination syndrome were also selected because these traits differ between early and later successional species (Körner 2005; Finegan 1984).

To reflect direct restoration goals that were to decrease presence of target shrub and vine species and increase tree regeneration (Bounds et al. 2014), growth form was selected.

Specific leaf area, a trait that correlates with relative growth rate and photosynthetic rates (Cornelissen et al. 2003; Pérez-Harguindeguy et al. 2013), was selected to observe changes in light levels that occur during forest succession (Lohbeck et al. 2014; Körner 2005), since SLA has been shown to change with changes in light conditions (Lambers, Chapin, and Pons 1998; Poorter 1999). Shade tolerance was also chosen to investigate how changes in light affected functional traits during ecological restoration.

Seed dispersal was selected because it has been shown to be an important trait that indicates successful native and non-native plants in urban ecosystems (Aronson, Handel, and Clemants 2007). Pollination was selected because it tends to indicate potential pollinator habitat or relationships in a system (Potts et al. 2003; Sargent and Ackerly 2008) and may indicate human selection for showy flowering plants (Dolan, Aronson, and Hipp 2017; Kendal, Williams, and Williams 2012), known to attract pollinators.

Traits were also selected if 50% or more of the species present in each forest layer contained data for chosen traits. For this reason, maximum tree height and lifespan were only analyzed among tree species in each forest layer.

2.1.2 Trait Data Sources

I assembled tables of species' functional traits by combining the following data sets: species occurring in the New York City Metropolitan region (Aronson and Williams, unpublished data), traits of species occurring in urban hardscapes (Frazee et al. 2019). From these data, I gathered functional trait data for species identified in the 2009-2010 vegetation sampling from Johnson and Handel (2016). To fill in gaps in trait data and traits of missing species, I used Michael Dirr's Manual of Woody Landscape Plants (Dirr 2009), TRY Plant Trait Database (Kattge et al. 2011) (see also Appendix A.1 for data contributors), USDA PLANTS database (USDA 2020), Missouri Botanic Garden Plant Finder (see Appendix A.2), USFS plant profiles (see Appendix A.2), and Lady Bird Johnson Wildflower Center's Native Plants Database (Lady Bird Johnson Wildflower Center 2020). TRY Plant Trait database is a database containing and compiling species functional trait datasets at a global scale (Kattge et al. 2011).

In creating queries for collecting functional trait data from TRY Plant Trait Database, I created a species list containing accepted taxonomic names as well as taxonomic synonyms was generated using the Integrated Taxonomic Information System (ITIS). This species list was then compared to the TRY plant species list for numeric identification codes.

I then assembled species codes for pulling data queries. TRY codes were also assembled for selected traits. Traits similar in name were also selected and codes assembled for pulling data. Using the species codes and functional trait codes, I generated a data request in TRY and only requested public datasets. Once requests were fulfilled, data files were downloaded as a tab delimited text file along with files describing the structure of the data and the TRY Intellectual Property Guidelines.

2.1.3 Trait Data Standardization

TRY functional trait data for seed mass, SLA, and maximum plant height were standardized to the units outlined in Table 4. I then calculated the species average for each trait. Only data noted to have an “Error Risk” of 3.5 or less were included in calculations for species average. This was because the TRY release documentation on data structure noted that data with an error risk of greater than 4 may indicate problems with the data (Kattge et al. 2011). For maximum plant height, TRY data records were only used in species trait averages if “trait name” or “data name” was entered as maximum height or max height.

Growth form data was originally recorded as codes corresponding to written standards from by Cornelissen et al. (2003). This data was then modified describe the respective growth form (see Table 4 for list of trait states). Herbaceous growth forms were modified to using similar growth form categories used in Dolan, Aronson, and Hipp (2017). Herbaceous growth forms used from Dolan, Aronson, and Hipp (2017) were fern, parasite, and graminoid. The “forb/herb” growth form used in Dolan, Aronson, and Hipp (2017) was further broken down by annual, biennial, and perennial (see Table 4) to reflect the multiple life histories that can be found in the broader growth form (Pérez-Harguindeguy et al. 2013).

Shade tolerance was determined using categories used in USDA PLANTS Characteristics (see Table 4). Species were placed into a shade tolerance category based on the category assigned in the USDA PLANTS Characteristics pages. Species missing shade tolerance data in USDA PLANTS characteristics, but possessed data in US Forest Service's Fire Effects Information System (see Appendix A.2), Plant Invaders of Mid-Atlantic Natural Areas (Swearingen et al. 2010), and horticultural resources (Dirr 2009; Lady Bird Johnson Wildflower Center 2020; *Missouri Botanical Garden Plant Finder* 2020) were assigned a shade tolerance category of "Tolerant", "Intermediate", or "Intolerant".

Seed dispersal categories were originally recorded as codes corresponding to categories from Cornelissen et al. (2003). Data used in this study are the categories used in Cornelissen et al. (2003). Instead of using codes, I used the corresponding names (see Table 4). This allowed for seed dispersal data from TRY and horticultural resources to be easily added and merged.

Pollination syndrome was categorized as "abiotic" or "biotic". Species with no pollination data in collaborator data, but data in TRY or horticultural resources were assigned a pollination syndrome category of abiotic if observed as wind or water pollinated, and biotic if observed as insect or bird pollinated.

Lifespan standards were based on standards used in USDA PLANTS. TRY data for lifespan consisted of numeric data. In this case, averages were calculated using protocols similar to seed mass and SLA then compared to the USDA PLANTS standards for lifespan.

Table 4. Plant functional traits used in this study. Data from listed sources were used to fill in species trait data and standardized to the units/categories outlined below.

Trait	Type of Data	Units/Categories
Growth form	Categorical	Tree, Shrub, Vine, Annual, Biennial, Perennial, Graminoid, Fern, Parasite
Shade tolerance	Categorical	Tolerant, Intermediate, Intolerant
Seed Dispersal	Categorical	Unassisted, Wind, Endo-zoochory, Exo-zoochory, Ant, Hoarding, Other
Pollination	Categorical	Abiotic, Biotic
Seed Mass	Continuous	milligrams (mg)
Specific Leaf Area (SLA)	Continuous	millimeters2/milligrams (mm2/mg)
Maximum Tree Height	Continuous	meters (m)
Tree Lifespan	Categorical	Long (>250 years), Moderate (100-250 years), Short (<100 years)

2.2 Species Abundance Data

2.2.2 Site Selection

In 1991, the Urban Forestry and Education Program (UFEP) was established by the City Parks Foundation with Natural Resources Group (NRG) (Bounds et al. 2014). Between 1991 and 1996 the UFEP ecological restoration projects in New York City parks removed target invasive species and planted trees (Bounds et al. 2014). These restoration projects occurred in parks in all 5 boroughs.

Johnson and Handel (2016) used records of these restoration projects from NYC Parks to select plots that had received ecological restoration under UFEP (referred to as restored plots from here on out). Restored plots were located in 3 parks: Inwood Park in Manhattan, Pelham Bay in the Bronx, and Prospect Park in

Brooklyn (Johnson and Handel 2016). Each park had 10 plots selected based on completeness and quality of records describing pre-restoration conditions, restoration treatments, and post-restoration management and monitoring (Johnson and Handel 2016).

In addition to restored plots, Johnson and Handel (2016) established comparison plots referred to as unrestored plots from here on out. They selected unrestored plots based on NRG's inventory records, documented as Entitation Reports (Bounds et al. 2014), completed between 1984 and 1990 that described locations with conditions similar to areas selected for restoration under UFEP, but were not restored during the same time period (Johnson and Handel 2016).

Entitation reports at the time of original mapping were used to identify plots dominated by invasive species, *Rosa multiflora, Ampelopsis brevipedunculata,* and *Celastrus orbiculatus.* Then management records and interviews with land managers were used to ensure and select plots located in sites that had not received any restoration work or management at the time of UFEP's projects or afterwards. Based on these criteria, Johnson and Handel (2016) established plots in the three parks: Cunningham Park in Queens and Pelham Bay and Van Cortlandt Parks in the Bronx. Each park had 10 unrestored plots, also sized at 20 m x 20 m (Johnson and Handel 2016).

2.2.3 Vegetation Sampling

Vegetation sampling took place in the established 20 m x 20 m plots in 2009 and 2010 (Johnson and Handel 2016). Johnson and Handel (2016) created plot the size and vegetation sampling protocols for comparability with the Permanent Forest

Reference Plot System (McDonnell et al. 1990) used in long term urban-rural gradient studies (McDonnell et al. 2008; Pouyat, McDonnell, and Pickett 1997; Cadenasso et al. 2007). Restored plots were sampled in between June and August of 2009 and unrestored plots were sampled between June and August of 2010 (Johnson and Handel 2016).

Johnson and Handel (2016) divided the vegetation sampling into 3 groups based on forest layer: canopy trees, woody understory (shrubs, vines, and tree saplings), and the ground layer. Trees with a diameter at breast height (DBH) of 2.54 cm or greater and height greater than 1 m in the entire 20 m x 20 m plot were identified and DBH measured. Multi-stemmed trees had their diameter measured below the point of branch division and height of division measured (Johnson and Handel 2016).

To sample the woody understory, Johnson and Handel (2016) randomly selected three 5 m x 5 m subplots within each 20 m x 20 m plot. Stems of shrub and vine species greater 1 m in height were counted in the subplots. Johnson and Handel (2016) also counted the stems of tree saplings, defined as tree species with less than 2.54 cm DBH and under 1 m in height, within subplots. If stems at ground level were within the subplot boundaries they were considered to be inside the subplot (Johnson and Handel 2016).

Ground layer sampling included herbaceous species and seedlings of woody species that were less than 1 m in height (Johnson and Handel 2016). To record ground layer species and species cover, Johnson and Handel (2016) created four 10 m long transects using a 1 cm wide measuring tape. Each transect started at a plot corner, extended 45˚ from the corner, and extended towards the plot center. Along each of these transects, Johnson and Handel (2016) measured centimeters of cover of each species to the whole centimeter using taut measuring tapes. Each species was sampled separately, making it possible for cover to exceed 100 cm where plants overlapped (Johnson and Handel 2016). Cover measured was from leaves and/or stems intercepting the transects with only living leaves and stems counted. Vegetation was considered continuous unless there was a gap of 5 cm or greater (Johnson and Handel 2016). Where shrub and/or vine cover over the transect line was greater than 1 m in height, selective hand pruning was performed to move the top layer of stems to allow ground layer vegetation under 1 m in height to be sampled (Johnson and Handel 2016).

Once each stratum was sampled according to the protocols mentioned above, Johnson and Handel (2016) inspected plots for other species not captured in the methods above and classified them as common or uncommon.

2.3 Data Preparation

To prepare species abundance data from Johnson and Handel (2016) and assemble functional trait data for functional composition and functional diversity calculations, I created separate files for species abundance and functional trait data and saved them as .CSV files. To prepare the functional trait data, I created a spreadsheet listed species by row and functional trait by column. Functional trait data was filled according to trait standards outlined in Table 2. The spreadsheet contained both continuous and nominal trait data. Noted in vegetation sampling methods, each layer of the forest had species abundance measured using different units. Sampled

DBH for trees was standardized to basal area (m^2/ha) for each species. Other layers utilized raw stem counts (understory) and centimeters of cover (ground layers) from Johnson and Handel (2016) to calculate functional trait composition. Because of this, each forest layer needed to have its own sheet.

To calculate functional diversity indices, I combined the species of sampled trees and woody understory because stem count for trees was also measured during Johnson and Handel's (2016) vegetation sampling. In each plot, stem counts for each layer were standardized to number of stems per hectare (stems/ha) then added together. The woody and herbaceous ground layers were combined together, as both were sampled using the same units (centimeters of cover).

2.4 Statistical Analyses

All functional composition, functional diversity calculations, and statistical analyses were calculated in R (R Core Team 2020).

To compare functional composition between restored and unrestored plots, I calculated the community weighted means for each plot using species abundance data and species functional trait data. To compare functional diversity of restored and unrestored conditions, I calculated the functional diversity indices of functional richness, functional evenness, and functional divergence (Mason et al. 2005; Villéger, Mason, and Mouillot 2008).

Calculations for functional trait composition and functional diversity indices were broken down by forest stratum. Strata were broken down as followed: Trees, woody understory (tree saplings, shrubs, and vines), woody species in the ground layer (tree seedlings, shrubs, and vines), and herbaceous species in the ground layer.

2.4.1 Community Weighted Means and Relative Frequency

Community weighted means (CWM) were for traits with continuous values (like seed mass). For categorical traits, like shade tolerance, I calculated relative frequency using the proportion of abundance by species with the trait state of interest. To calculate CWM, I used the functcomp() function in the FD package for R (Laliberté, Legendre, and Shipley 2014). These calculations created plot averages for seed mass (mg), SLA (mm2/ha), and maximum plant height (m) using species abundance data and species averages for each trait. This was done for each trait in each forest layer. Using the same function, I calculated the relative frequencies for categorical traits by trait states in each plot.

2.4.2 Functional Diversity Indices

I calculated functional diversity indices scores using the dbfd() function in the R package FD (Laliberté, Legendre, and Shipley 2014). This function allowed for the calculation of multidimensional functional diversity indices.

2.4.3 Statistical Tests and Boxplots

To test for normality, histograms plotting the percent cover for trait states or trait averages for restored and unrestored plots were generated using the hist() function (R Core Team 2020) (see Figures in Appendix A.5). None of the data had normal distributions, which did not allow the use of t-tests as an assumption of t-tests is that data are normally distributed. Instead, I used the non-parametric Mann Whitney U test (also known as Wilcoxon Rank Sum test) to test for significant differences in functional trait composition and functional diversity indices between restored and unrestored plots. The confidence level for each of these tests was set to 95%.

Box and whisker plots visualizing the analyzed differences in functional trait composition and functional diversity indices were generated using the ggplot function in the ggplot2 package in R (Wickham 2016; R Core Team 2020). Displayed in each of the box and whisker plots are: the median (solid horizontal line within the box, represents the 50^{th} percentile), mean (dotted line within the box), 25^{th} and 75^{th} percentile (lower and upper box ends), and whiskers extending to further plots that fall within ±1.5 times the interquartile range. Points falling outside of the box and whiskers represent outliers.

2.5 Data Management Plan

2.5.1 Documentation

All sources used for assembling functional trait data were documented throughout the study.

Code used in R was annotated in R Markdown where I described the necessary steps needed to prepare for functional diversity and community weighted mean calculations and how to run the calculations using the dbfd() and functcomp() functions. I also documented code I used for statistical analysis and creating graphics. All libraries and packages were listed in R Markdown documents.

2.5.2 Data File Types

Functional trait data from TRY was downloaded as a .txt file. Once imported into R, it was exported as a .csv file since this file type can be easily viewed in Microsoft Excel.

All data tables that were going to be imported into R were stored as .csv files and all tables exported out of R were stored as .csv files. Graphs created in R were downloaded as .pdf files. R Markdown files were saved as .html files.

2.5.3 Data Storage

All data files used in this study were stored on the Johnson Lab Google Drive in the “NYC Trait Study” folder, my personal laptop, and my personal Google Drive. Files were backed up every time there were edits made to the data tables or code.

3. Results

Fifteen to twenty years after ecological restoration in New York City urban forest patches, restored plots differed from unrestored plots in their functional composition and functional diversity (see Table 5 and 6).

Table 5. P-Values and summarized trends in functional composition by forest stratum. Asterisks indicate significant differences (Mann-Whitney U Test, ns = Not Significant, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Where there are significant differences, the direction of difference is indicated.

	Trait	Trait State	P-value		Direction of Difference
Canopy					
	Shade Tolerance	Tolerant	0.0004	**	Restored > Unrestored
		Intermediate	0.1941	ns	NA
		Intolerant	0.1139	ns	NA
	Seed Mass		0.08234	ns	NA
	SLA		0.9538	ns	NA
	Maximum Plant Height		0.0191	*	Restored > Unrestored
	Seed Dispersal	Unassisted	0.1319	ns	NA
		Wind	0.1731	ns	NA
		Endo-zoochory	0.02022	*	Restored < Unrestored
		Hoarding	0.0125	*	Restored > Unrestored
	Pollination	Abiotic	0.02171	*	Restored > Unrestored
		Biotic	0.02171	*	Restored < Unrestored
	Lifespan	Long	0.0815	ns	NA
		Moderate	0.2398	ns	NA
		Short	0.2865	ns	NA
Woody Understory					
	Growth Form	Tree	1.69E-07	***	Restored > Unrestored
		Shrub	0.813	ns	NA
		Vine	1.76E-06	***	Restored < Unrestored
	Shade Tolerance	Tolerant	0.01496	*	Restored < Unrestored
		Intermediate	0.02812	*	
		Intolerant	0.04688	ns	NA
	Seed Mass		5.05E-05	***	Restored > Unrestored
	SLA		0.0266	*	Restored > Unrestored

	Maximum Plant Height		0.3500	ns	NA
	Seed Dispersal	Unassisted	0.7935	ns	NA
		Wind	6.40E-06	***	Restored > Unrestored
		Endo-zoochory	7.44E-09	***	Restored < Unrestored
		Hoarding	0.0026	**	Restored > Unrestored
	Pollination	Abiotic	2.15E-07	***	Restored > Unrestored
		Biotic	3.83E-07	***	Restored < Unrestored
	Lifespan	Long	0.0118	*	Restored > Unrestored
		Moderate	0.1684	ns	NA
		Short	0.0407	*	Restored < Unrestored
Woody Ground Layer					
	Growth Form	Tree	0.0017	***	Restored > Unrestored
		Shrub	0.2760	ns	NA
		Vine	0.3572	ns	NA
	Shade Tolerance	Tolerant	0.564	ns	NA
		Intermediate	0.0057	**	Restored > Unrestored
		Intolerant	0.0014	***	Restored < Unrestored
	Seed Mass		0.0055	**	Restored > Unrestored
	SLA		0.69	ns	NA
	Maximum Plant Height		0.0803	ns	NA
	Seed Dispersal	Unassisted	0.8588	ns	NA
		Wind	0.0033	**	Restored > Unrestored
		Endo-zoochory	0.0010	**	Restored < Unrestored
		Hoarding	0.0922	ns	NA
		Ants	0.3173	ns	NA
	Pollination	Abiotic	0.0339	ns	NA
		Biotic	0.0750	ns	NA
	Lifespan	Long	0.7380	ns	NA
		Moderate	0.1691	ns	NA
		Short	0.1003	ns	NA
Herbaceous Ground Layer					
	Growth Form	Annual	0.5848	ns	NA
		Perennial	3.93E-05	***	Restored > Unrestored
		Biennial	0.0002	***	Restored < Unrestored
		Graminoid	0.0165	*	Restored < Unrestored
		Fern	0.3772	ns	NA
		Parasite	0.3006	ns	NA
	Shade Tolerance	Tolerant	0.0036	***	Restored < Unrestored
		Intermediate	0.0039	***	Restored > Unrestored
		Intolerant	0.2674	ns	NA
	Seed Mass		0.0527	ns	NA
	SLA		0.2019	ns	NA
	Seed Dispersal	Unassisted	0.0270	*	NA
		Wind	0.9619	ns	NA
		Endo-zoochory	0.6667	ns	NA

	Exo-zoochory	0.0051	**	Restored > Unrestored
	Other	0.9232	ns	NA
Pollination	Abiotic	0.03714	*	Restored > Unrestored
	Biotic	0.1046	ns	NA

Table 6. P-values and summarized trends of different functional indices. Asterisks indicate significant differences (Mann-Whitney U Test, ns = Not Significant, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Where there are significant differences, the direction of difference is indicated.

Functional Diversity Indices	**Forest Layer**	**P-value**		**Direction of Difference**
Functional	Canopy and Woody			
Richness	Understory	0.9474	ns	NA
	Ground Layer	0.7524	ns	NA
Functional	Canopy and Woody			
Evenness	Understory	0.0120	*	Restored > Unrestored
	Ground Layer	0.0005	**	Restored > Unrestored
Functional	Canopy and Woody			
Divergence	Understory	0.9240	ns	NA
	Ground Layer	0.0823	ns	NA

3.1 Functional Composition

The woody understory and ground layer of restored plots contained for trees compared to unrestored plots. Shade tolerant species were more abundant in trees and herbaceous species in the ground and less abundant in the woody understory of restored plots. Wind dispersed and seed hoarded species were more abundant in restored plots, while endo-zoochoric species were less abundant. There was a greater abundance of plants with larger average seed mass and average SLA in restored plots. Tree community composition of restored plots contained a greater proportion of long-lived trees while unrestored plots had more short-lived trees. Abiotically pollinated species were significantly more abundant in woody species and less abundant in herbaceous species of restored plots. A table of P-Values calculated for each analysis can be found at the end of the results section.

3.1.1 Growth Form

Growth forms differed between restored and unrestored plots. In addition to differences in growth form, there were also differences in most abundant species (see Appendix A.3 for more information).

3.1.1.1 Woody Understory Stems by Growth Form

Woody understory plants in restored plots significantly differed from unrestored plots in the proportion of stems that belonged to tree and vine species. Restored plots had greater relative abundances of tree and vine stems in comparison unrestored plots (see Figure 3). The proportion of shrub stems did not differ between restored and unrestored plots (see Figure 3), however dominant shrub species did differ between restored and unrestored plots (see Table A.15). Total shrub stems in restored plots were lower than unrestored plots (see Figure 4).

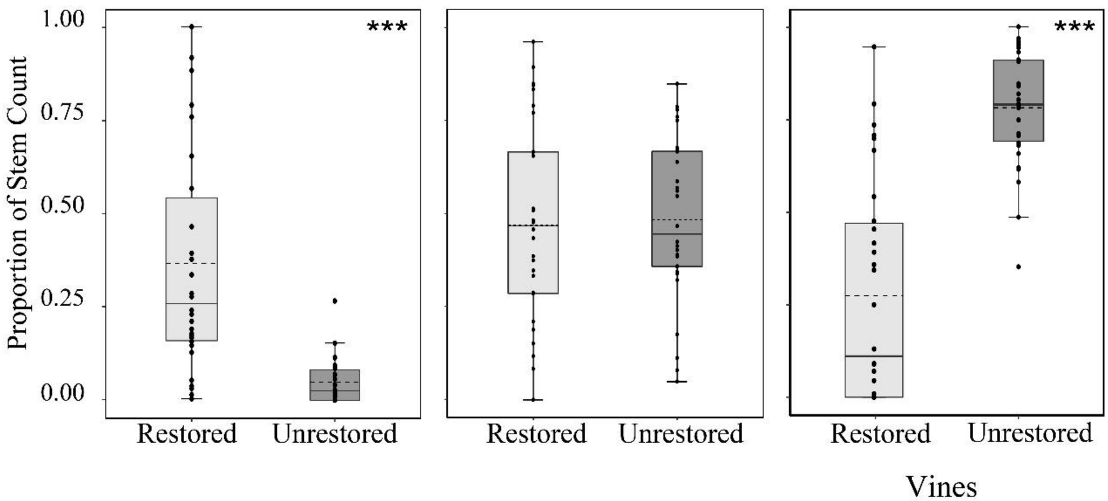

Figure 3. Woody Understory by growth form in restored (n=30) and unrestored (n=30) plots. Woody understory stems include tree saplings, shrubs, and vines > 1 m in height and < 2.5 cm DBH. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

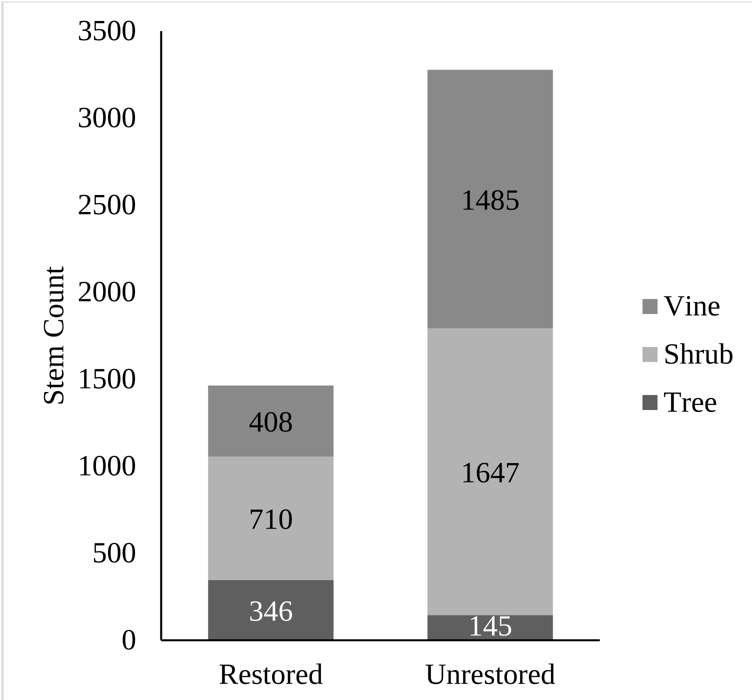

Figure 4. Woody understory stems by growth form. Stems consisted of shrubs, vines, and trees > 1 m in height and a DBH < 2.54 cm. Restored plots had less stems in the woody understory then unrestored plots.

3.1.1.2 Ground Layer Cover by Growth Form

Growth form in the ground layer of restored plots significantly differed from unrestored plots. Restored plots had greater relative abundances of tree seedlings, shrubs, vines, perennial herbs, and graminoids (see Figure 5). As a whole, restored plots had less total cover in the ground layer than unrestored plots.

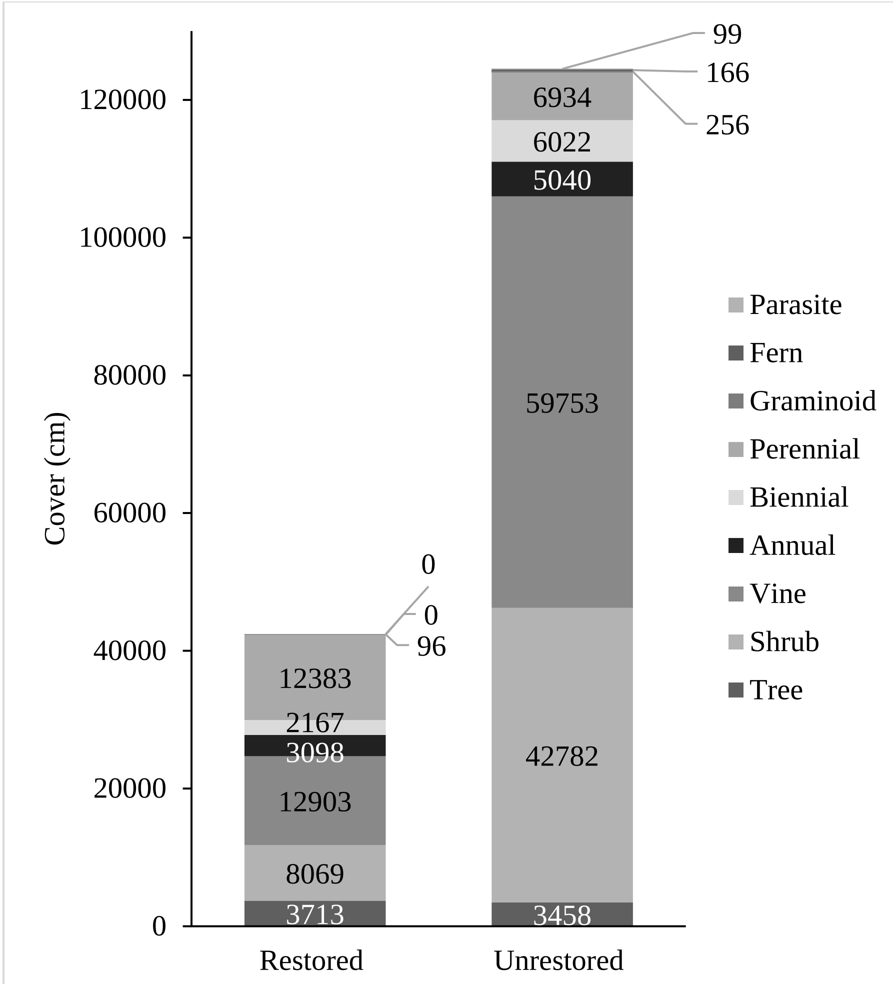

Figure 5. Total ground layer cover (cm) by growth form. Species in the ground layer included herbaceous species and woody species consisting of tree seedlings, shrubs, and vines < 1 m in height. Restored (n=30) plots had less cover by species in the ground layer than unrestored (n=30) plots.

3.1.1.3 Woody Species in the Ground Layer by Growth Form

Woody plant cover in the ground layer of restored plots had greater relative abundance of trees than unrestored plots (see Figure 6). Proportional woody plant cover of shrub and vine species did not differ between restored and unrestored plots (Figure 6). The most abundant shrub species in unrestored plots was *Rosa multiflora* (see Table A.30). In restored plots, *R. multiflora* and *Lindera benzoin* were the two most abundant shrub species (see Table A.30). Dominant vine species also differed between restored and unrestored plots (see Table A.34). The most abundant vine species in the ground layer of restored plots were *Toxicodendron radicans* and *Parthenocissus quinquefolia*. In unrestored plots, the most abundant vine in the ground layer was target invasive species, *Ampelopsis brevipedunculata*.

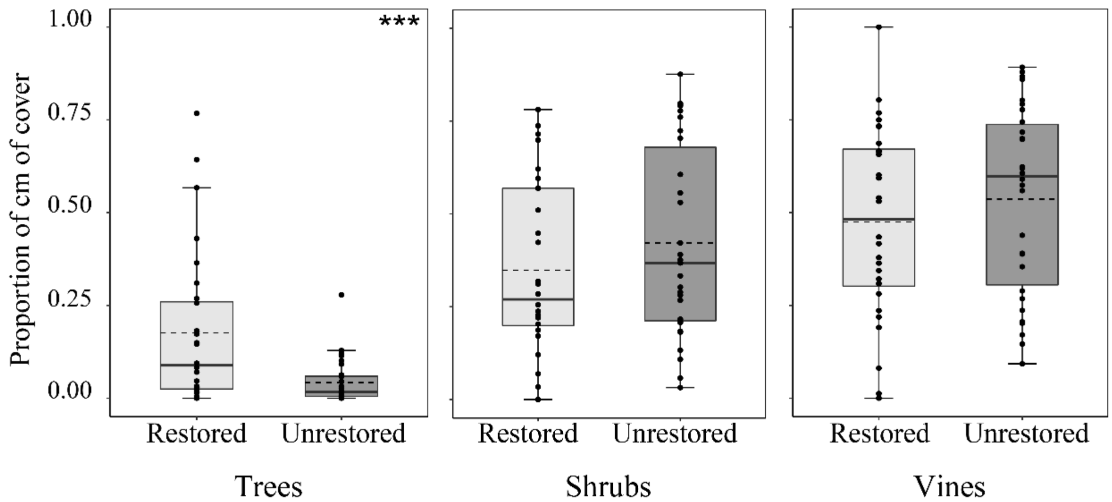

Figure 6. Woody species in the ground layer by growth form in restored (n=30) and unrestored (n=30) plots. Woody species in the ground layer included tree seedlings, shrubs, and vines < 1 m in height. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.1.4 Herbaceous Ground Layer Cover by Growth Form

Biennial and perennial plants had significantly greater relative abundances in restored plots than unrestored plots (see Figure 7). The biennial species *Allaria petiolata* was abundant in restored and unrestored plots and the only biennial species in restored plots (see Table A.48). While a rare growth form found in both plot types, graminoids made up a greater proportion of herbaceous ground layer cover in unrestored plots (see Figure 7). Restored and unrestored plots did not differ in cover by annual, fern, and parasite species (see Figure 7).

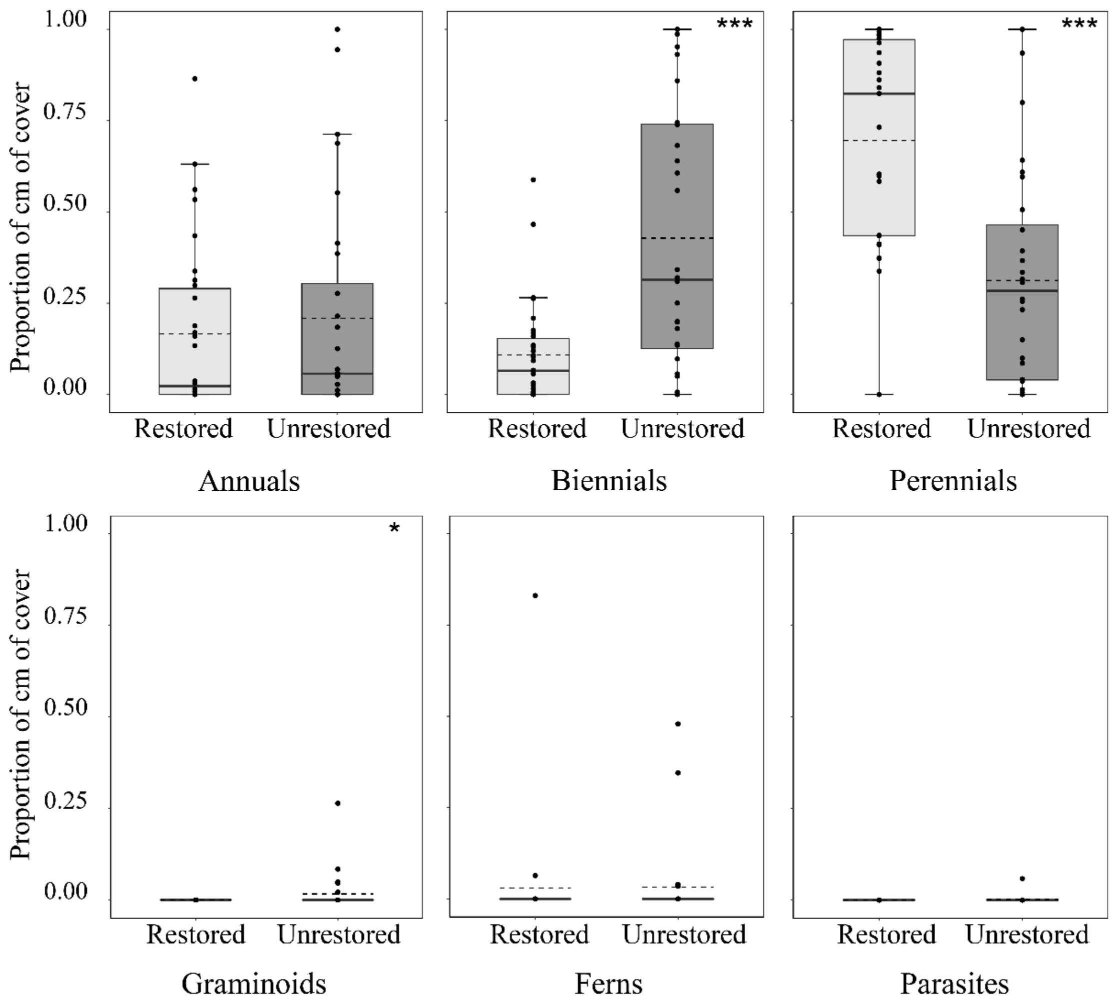

Figure 7. Herbaceous species in the ground layer by growth form in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.2 Shade Tolerance

Restored and unrestored plots had different relative abundances of species with shade tolerance, intermediate shade tolerance, and shade intolerance. There were also differences in most abundant tree species with intermediate shade tolerance and shade tolerant species in the woody understory.

3.1.2.1 Shade Tolerance of Tree Species

There was a greater relative abundance of shade tolerant trees in restored plots (see Figure 8). In both plot types, *Fraxinus pennsylvanica* was the most abundant shade tolerant tree species. Basal area of *F. pennsylvanica* was over three times greater in restored plots and occurred in three times the number of restored plots compared to unrestored plots (see Table A.2).

The relative abundance of tree species with intermediate shade tolerance did not differ between restored and unrestored plots (see Figure 8), however the most abundant species with intermediate shade tolerance differed between restored and unrestored plots (see Table A.3). Most abundant shade intolerant trees of restored plots were *Robinia pseudoacacia, Carya cordiformis, Prunus serotina*, and *Liriodendron tulipifera* (see Table A.4). In unrestored plots, *Sassafras albidum* and *R. pseudoacacia* were the most abundant shade intolerant trees (see Table A.4).

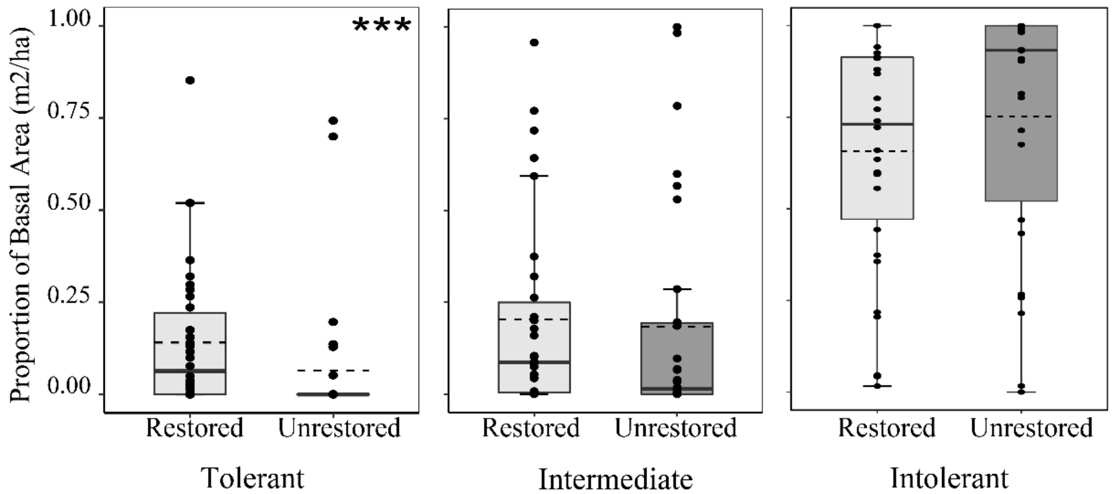

Figure 8. Trees by shade tolerance in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.2.2 Shade Tolerance of Species in the Woody Understory

Restored plots had lower relative abundances of shade tolerant species in the woody understory than unrestored plots (see Figure 9). Intermediate shade tolerant species had greater relative abundances in restored plots (see Figure 9). Shade intolerant species in the woody understory did not differ between restored and unrestored plots (see Figure 9). The majority of shade tolerant stems in unrestored plots were stems of *Lonicera japonica*, *Rubus pensilvanicus*, and *Celastrus orbiculatus*. These three species, based on their importance value index (IVI), were the most abundant in unrestored plots and occurred in the majority of unrestored plots (see Table A.17). In restored plots, *Lonicera japonica*, *Acer negundo* and *Rubus* *pensilvanicus* were the most abundant shade tolerant species (see Table A.17). The three most abundant shade tolerant species in unrestored plots had over three times the number of stems and were present in over twice the number of plots than the three most abundant shade tolerant species in restored plots (see Table A.18).

The shade intolerant species with the largest stem count in restored and unrestored plots was *Rosa multiflora*. *R multiflora* had over six times the number of stems in unrestored plots than in restored plots. It was also present in almost three times the number of unrestored plots than restored plots (see Table A.19).

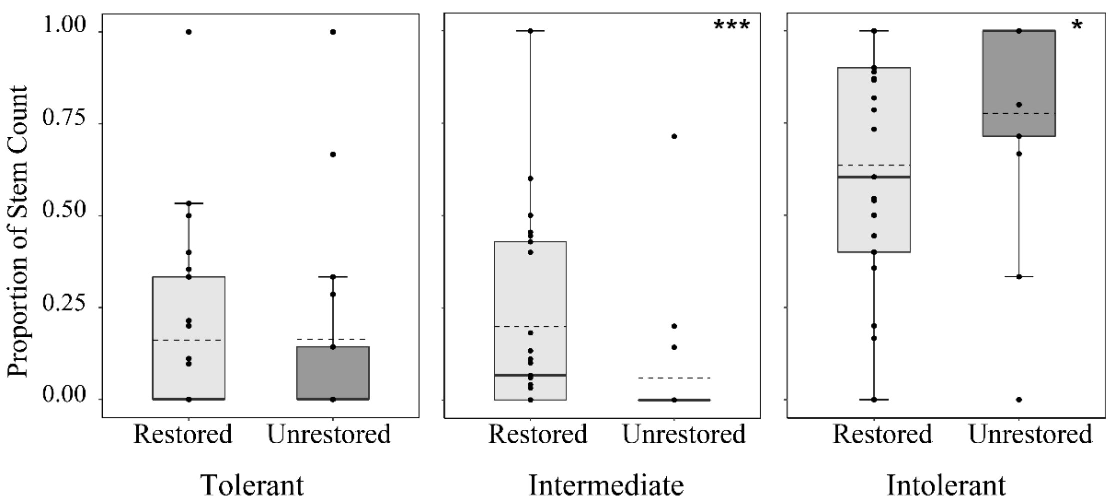

Figure 9. Relative abundance of woody understory stems by shade tolerance in restored (n=30) and unrestored (n=30) plots. Stems in the woody understory include shrubs, vines, and tree saplings with height > 1 m and DBH < 2.54 cm for saplings. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.2.3 Shade Tolerance of Woody Species in the Ground Layer

Species with intermediate shade tolerant and shade intolerant species covered a significantly greater proportion of the ground layer in restored plots than unrestored plots (see Figure 10). Restored and unrestored plots did not differ in the proportion of ground layer cover by shade tolerant woody species (see Figure 10). Tree species in the ground layer of restored and unrestored plots did not differ in relative abundance of species with shade tolerance (see Figure 11).

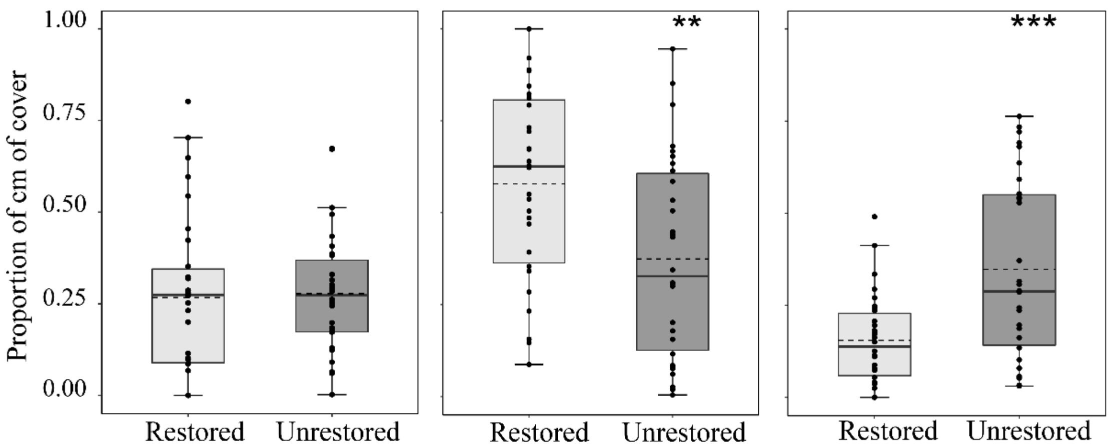

Figure 10. Woody species in the ground layer by shade tolerance in restored (n=30) and unrestored (n=30) plots. Woody species in the ground layer include shrubs, vines, and tree seedlings < 1 m in height. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

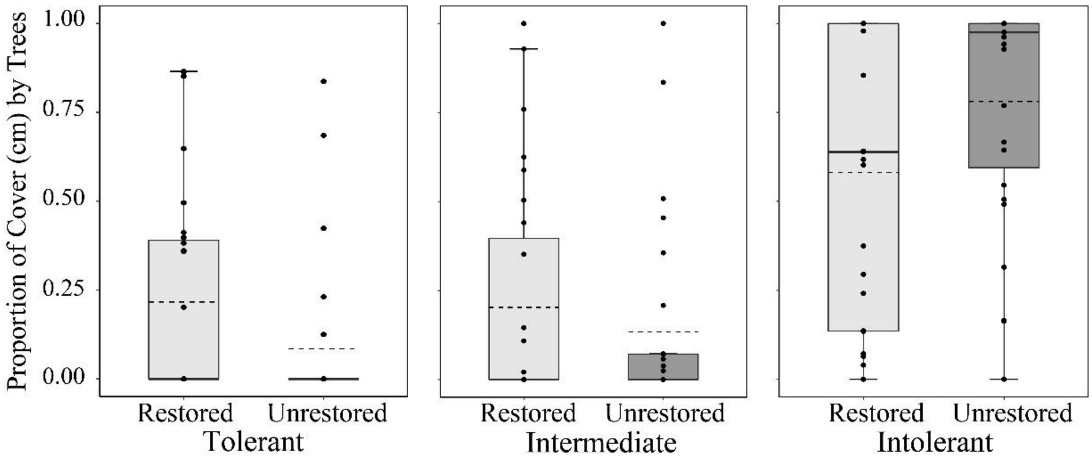

Figure 11. Tree seedling species in the ground layer by shade tolerance in restored (n=30) and unrestored (n=30) plots. All tree seedlings were tree species < 1 m in height. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.2.4 Shade Tolerance of Herbaceous Species in the Ground Layer

Restored plots had a greater relative abundance of herbaceous species with intermediate shade tolerance in restored plots compared to unrestored plots (see Figure 12). There was a greater proportion of herbaceous species with shade tolerance in unrestored plots. The proportion of shade intolerant herbaceous cover did not differ between restored and unrestored plots (see Figure 12).

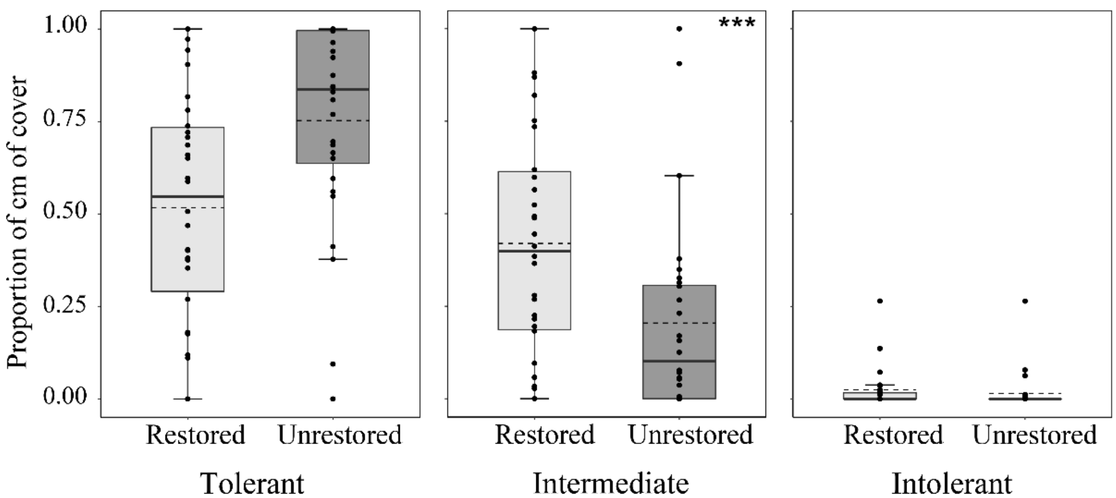

Figure 12. Herbaceous species in the ground layer by shade tolerance in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.3 Seed Mass

Average seed mass of woody understory communities and communities of woody species in the ground layer differed between restored and unrestored plots.

3.1.3.1 Seed Mass of Tree Species

Tree community compositions did not have different average seed masses between restored and unrestored plots (see Figure 13).

3.1.3.2 Seed Mass of Species in the Woody Understory

The average seed mass in the woody understory community was significantly greater in restored plots (see Figure 13). Tree sapling communities in the woody understory did not differ in average seed mass between restored and unrestored plots (see Figure 13).

3.1.3.3 Seed Mass of Woody Species in the Ground Layer

Restored plots had a significantly greater proportion of cover by woody species with larger average seed masses in the ground layer than unrestored plots (see Figure 13). Tree seedling communities in the ground layer did not differ in average seed mass between restored and unrestored plots (see Figure 13).

3.1.3.4 Seed Mass of Herbaceous Species in the Ground Layer

Communities of herbaceous species in the ground layer did not differ in average seed mass between restored and unrestored plots (see Figure 13).

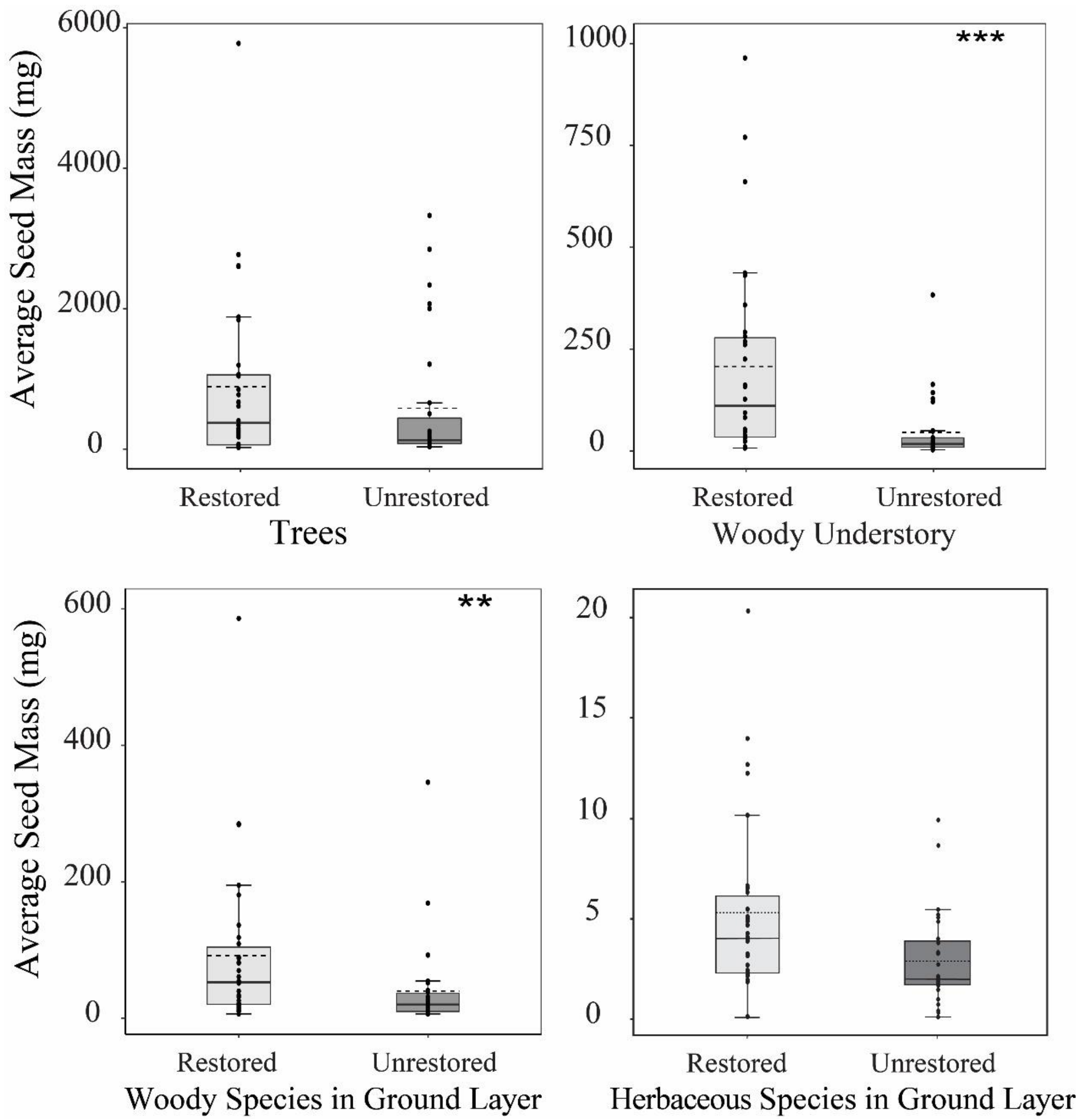

Figure 13. Average seed mass (mg) of forest stratum communities in restored (n=30) and unrestored (n=30) plots. Average seed mass in each plot was calculated using community weighted means, which used species abundance and average seed mass for each species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.4 Specific Leaf Area

Average SLA only differed between woody understory communities and tree seedlings in the ground layer of restored and unrestored plots.

3.1.4.1 Specific Leaf Area of Trees

Tree communities did not have different average SLA between restored and unrestored plots (see Figure 14).

3.1.4.2 Specific Leaf Area of Species in the Woody Understory

Restored plots had a significantly greater proportion of stems of species with larger average SLA in the woody understory compared to unrestored plots (see Figure 14). Tree saplings in the woody understory of restored and unrestored plots did not have different average SLA (see Figure 14).

3.1.4.3 Specific Leaf Area of Woody Species in the Ground Layer

Average SLA of the proportion of cover by woody species in the ground layer did not significantly differ between restored and unrestored plots (see Figure 14). Tree seedlings in the ground layer had greater average SLA in unrestored plots (Figure 14).

3.1.4.4 Specific Leaf Area of Herbaceous Species in the Ground Layer

The communities of herbaceous species in the ground layer had similar average SLA in restored and unrestored plots (see Figure 14).

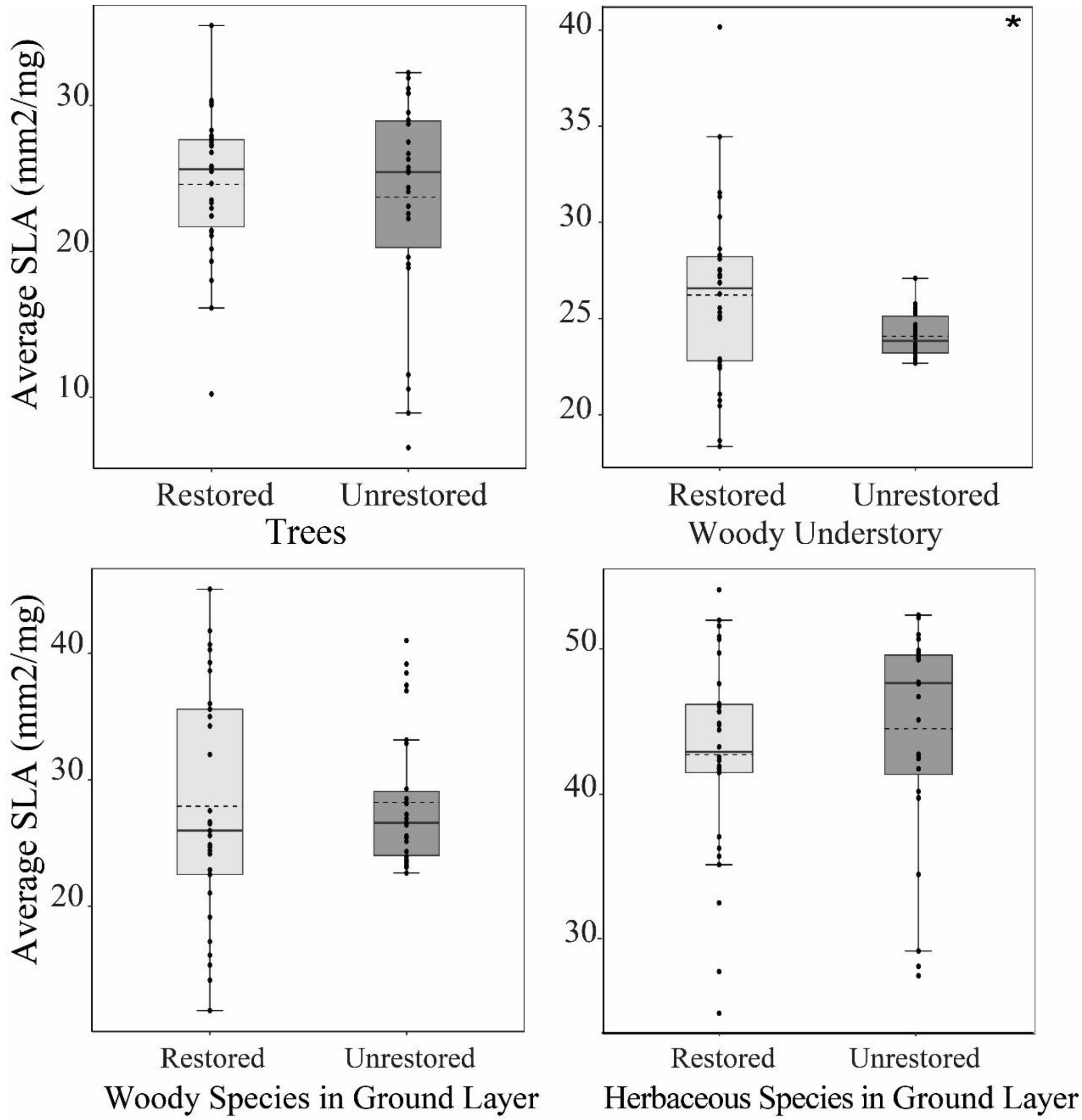

Figure 14. Average SLA (mm^2/mg) of forest stratum communities in restored (n=30) and unrestored (n=30) plots. Average SLA in each plot was calculated using community weighted means, which used species abundance and average SLA for each species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.5 Maximum Tree Height

Average maximum tree height only differed in tree communities between restored and unrestored plots.

3.1.5.1 Maximum Tree Height of Trees

Trees had significantly greater average maximum tree height in restored plots (see Figure 15). Trees in restored plots had larger relative abundances of *Carya cordiformis* and *Liriodendron tulipifera*. These species were some of the tallest tree species found in both plot types with average maximum plant heights of 33.7m and 44.6m respectively. The three most abundant trees in unrestored plots were the shorter species *Sassafras albidum, Robinia pseudoacacia,* and *Prunus serotina*. Average maximum plant height for these species were 22.4 m, 17.1 m, and 17.8 m respectively.

3.1.5.2 Maximum Tree Height of Tree Saplings in the Woody Understory

Tree saplings in the woody understory did not have significantly difference average maximum tree heights between restored and unrestored plots (see Figure 15).

3.1.5.3 Maximum Tree Height of Tree Seedlings in the Ground Layer

Average maximum tree height of tree seedlings in the ground layer did not differ between restored and unrestored plots (see Figure 15).

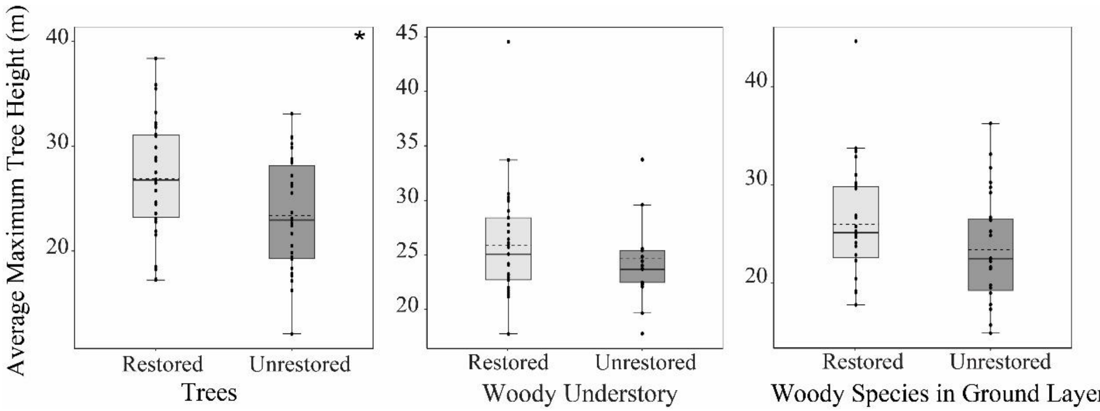

Figure 15. Average maximum tree height (m) of forest stratum communities in restored (n=30) and unrestored (n=30) plots. Average maximum tree height in each plot was calculated using community weighted means, which used species abundance and average maximum tree height for each species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6 Seed Dispersal

Restored and unrestored plots had differed in seed dispersal methods. In addition, abundant endozoochoric species differed between restored and unrestored plots.

3.1.6.1 Unassisted Seed Dispersal

Relative abundance of species with unassisted seed dispersal only differed significantly in herbaceous species in the ground layer of restored and unrestored plots. Unassisted seed dispersal was rare among woody species, with only 7 of 106 woody species having this dispersal method.

3.1.6.1.1 Unassisted Seed Dispersal in Trees

Tree communities did not differ in the relative abundance of species with unassisted seed dispersal between restored and unrestored plots (see Figure 16).

3.1.6.1.2 Unassisted Seed Dispersal in Species in the Woody Understory

There was no significant difference in the relative abundance of species with unassisted seed dispersal (see Figure 16). The relative abundance of tree saplings with unassisted seed dispersal was significantly greater in the woody understory of unrestored plots (see Figure 17). This was driven by the lack of tree saplings with unassisted seed dispersal in the ground layer of restored plots (see Table A.20).

3.1.6.1.3 Unassisted Seed Dispersal in Woody Species in the Ground Layer

Woody species with unassisted seed dispersal did not have differ in the proportion of cover in the ground layers of restored and unrestored plots (see Figure 16). There was no significant difference in the proportion of cover by tree seedlings with unassisted seed dispersal in the ground layers of restored and unrestored plots (see Figure 17).

3.1.6.1.4 Unassisted Seed Dispersal in Herbaceous Species in the Ground Layer

Herbaceous species with unassisted seed dispersal covered a greater proportion of the ground layer in unrestored plots (see Figure 16). The most abundant species with unassisted seed dispersal in restored and unrestored plots was *Alliaria petiolata*, however total centimeters of cover by *A. petiolata* in unrestored plots was double the total cover in restored plots (see Table A.55).

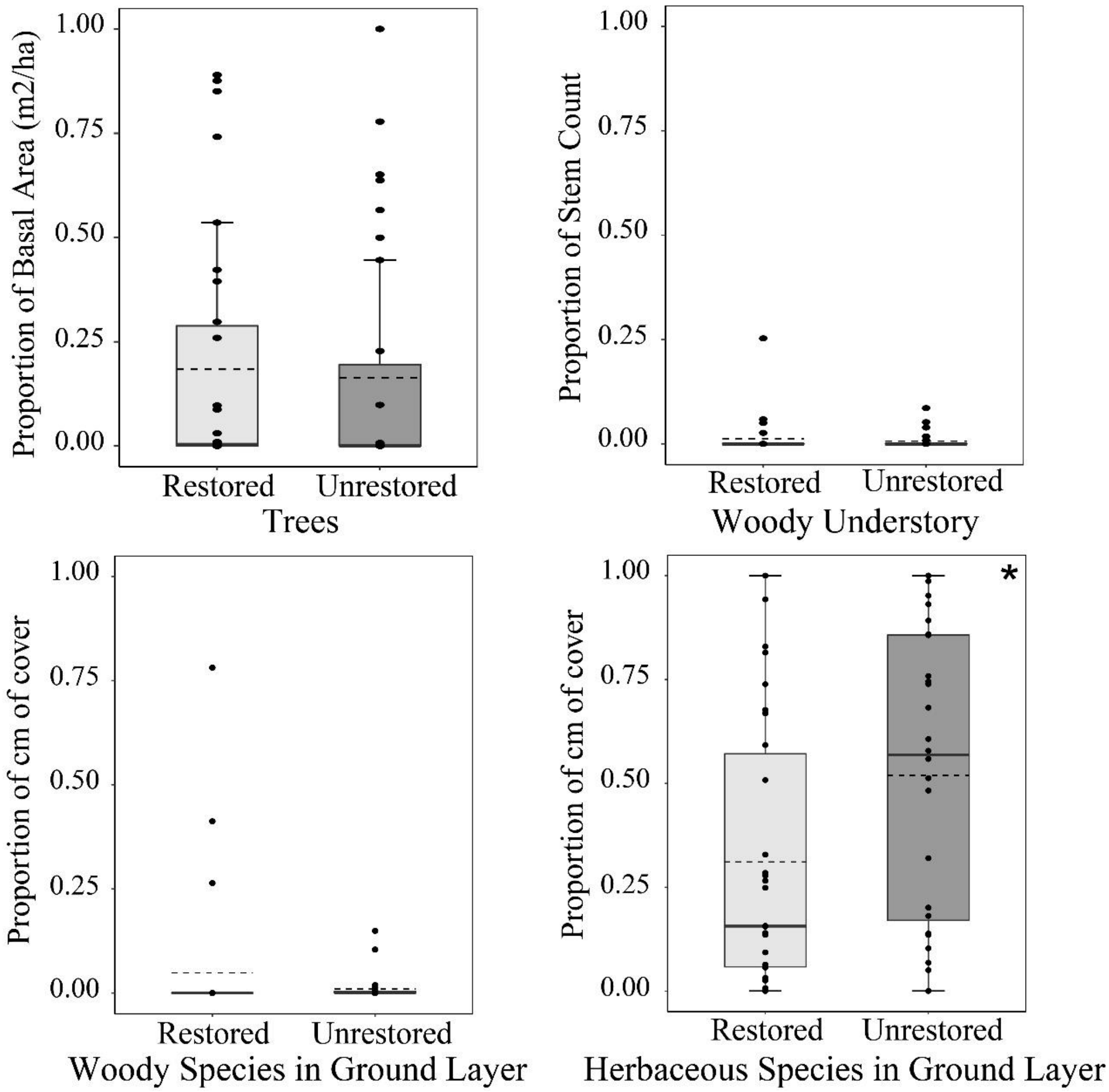

Figure 16. Relative abundance of species with unassisted seed dispersal by forest stratum communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

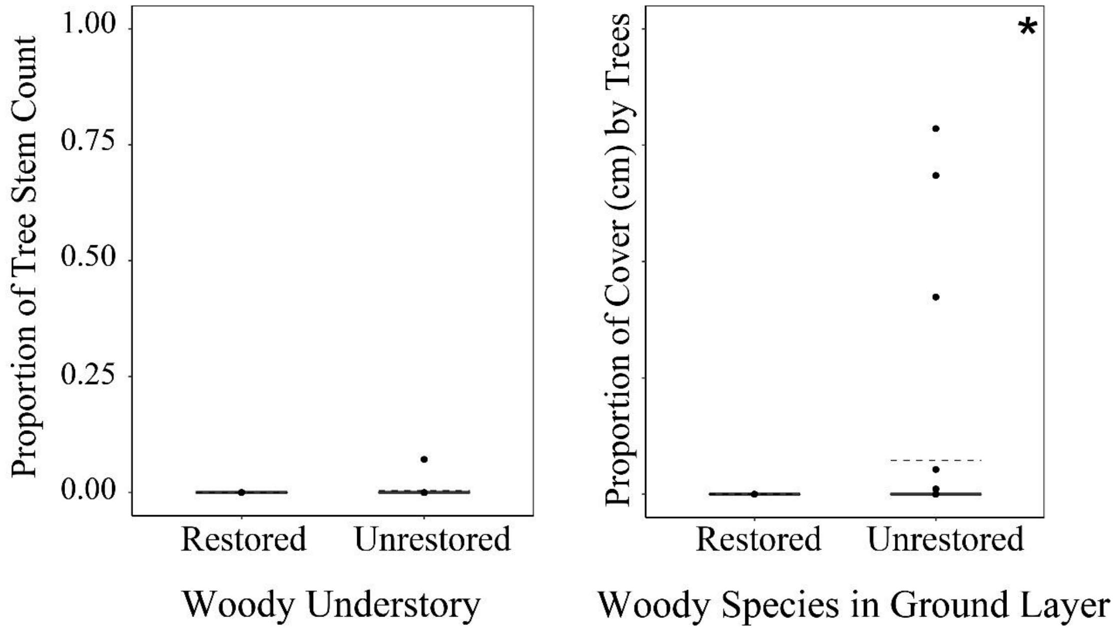

Figure 17. Relative abundance of tree saplings (left) and tree seedlings (right) with unassisted seed dispersal in forest stratum communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.2 Wind Dispersal

3.1.6.2.1 Wind Dispersal in Trees

The relative abundance of trees with wind dispersal did not significantly differ between restored and unrestored plots (see Figure 18).

3.1.6.2.2 Wind Dispersal in Species in the Woody Understory

Stems of species with wind dispersal in the woody understory were more abundant in restored plots (see Figure 18). There was also a greater relative abundance of tree saplings with wind dispersal in the woody understory of restored plots (see Figure 19). Of the 14 wind dispersed species in the woody understory, 13 were tree species (see Table A. 21).

3.1.6.2.3 Wind Dispersal in Woody Species in the Ground Layer

There were greater proportions of cover by woody species with wind dispersal in the ground layer in restored plots (see Figure 18). Restored plots had a greater relative abundance of tree seedlings with wind dispersal compared to unrestored plots (see Figure 19). There were 13 woody species in the ground layer that are wind dispersed, 12 of which were also tree species (see Table A.35).

3.1.6.2.4 Wind Dispersal in Herbaceous Species in the Ground Layer

Herbaceous species with wind dispersal in the ground layer did not significantly differ in relative abundance between restored and unrestored plots (see Figure 18).

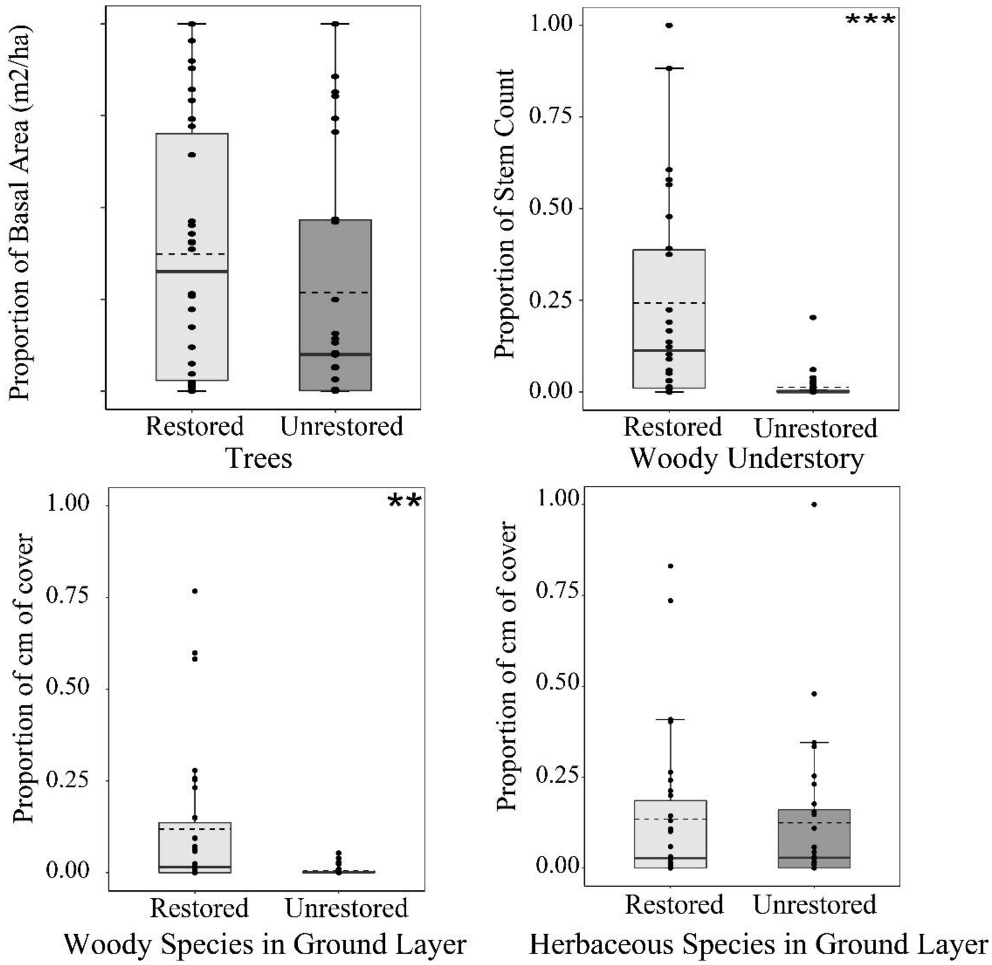

Figure 18. Relative abundance of wind dispersed species in forest stratum communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

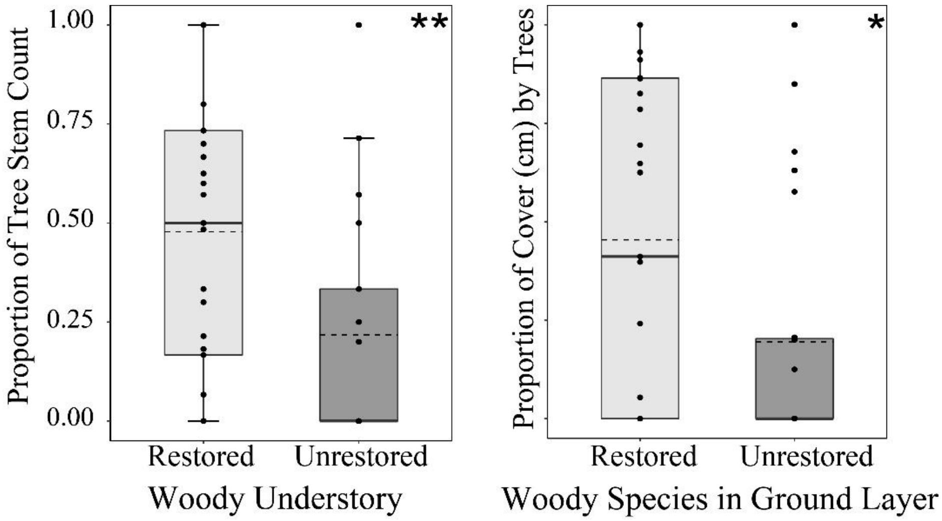

Figure 19. Relative abundance of wind dispersed tree saplings (left) and tree seedlings (right) in forest stratum communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.3 Endozoochory

3.1.6.2.4 Endozoochory in Trees

Endozoochoric trees in unrestored plots had greater relative abundances than restored plots (see Figure 20). In restored plots, the most abundant endozoochoric species was *Prunus serotina* while the most abundant endozoochoric species in unrestored plots was *Sassafras albidum* (see Table A.7). *S. albidum* in unrestored plots had three times more total basal area than *P. serotina* in restored plots (see Table A.7).

3.1.6.2.4 Endozoochory in Species in the Woody Understory

Restored plots had a significantly lower relative abundance of endozoochoric species in the woody understory (see Figure 20). Endozoochoric stems in the woody understory were primarily shrub and vine species. In restored plots, the most abundant endozoochoric species was native *Lindera benzoin* (see Table A.22). The most abundant endozoochoric species in unrestored plots was target invasive species *Rosa multiflora*, which had over three times the total amount of stems than the most abundant endozoochoric species in restored plots, *L. benzoin* (see Table A.22).

There was a greater relative abundance of endozoochoric trees in unrestored plots (see Figure 21). The most abundant endozoochoric tree species in the woody understory of unrestored plots was *Sassafras albidum* while in restored plots, the most abundant endozoochoric tree species was *Prunus serotina* (see Table A.23).

3.1.6.2.4 Endozoochory in Woody Species in the Ground Layer

Unrestored plots had a greater relative abundance of endozoochoric woody species in the ground layer. The most abundant woody endozoochoric species in the ground layer was *Rosa multiflora*. *R. multiflora* in unrestored plots had over eight times more cover, with 30,408 cm of cover, than the most abundant woody endozoochoric species in restored plots, *Toxicodendron radicans*, which had 3758 cm of cover (see Table A.37). *R. multiflora* was also present in 97% of unrestored plots while *T. radicans* was present in 80% of restored plots.

In the ground layer, there was more cover by endozoochoric tree species in unrestored plots (see Figure 21). The most abundant endozoochoric tree in the ground layer of unrestored plots was *Sassafras albidum*, which had over three times the amount of cover than the most abundant endozoochoric tree species in restored plots, *Prunus serotina* (see Table A.37).

3.1.6.2.4 Endozoochory in Herbaceous Species in the Ground Layer

There was no significant difference in the relative abundance of endozoochoric herbaceous species in the ground layer of restored and unrestored plots (see Figure 20).

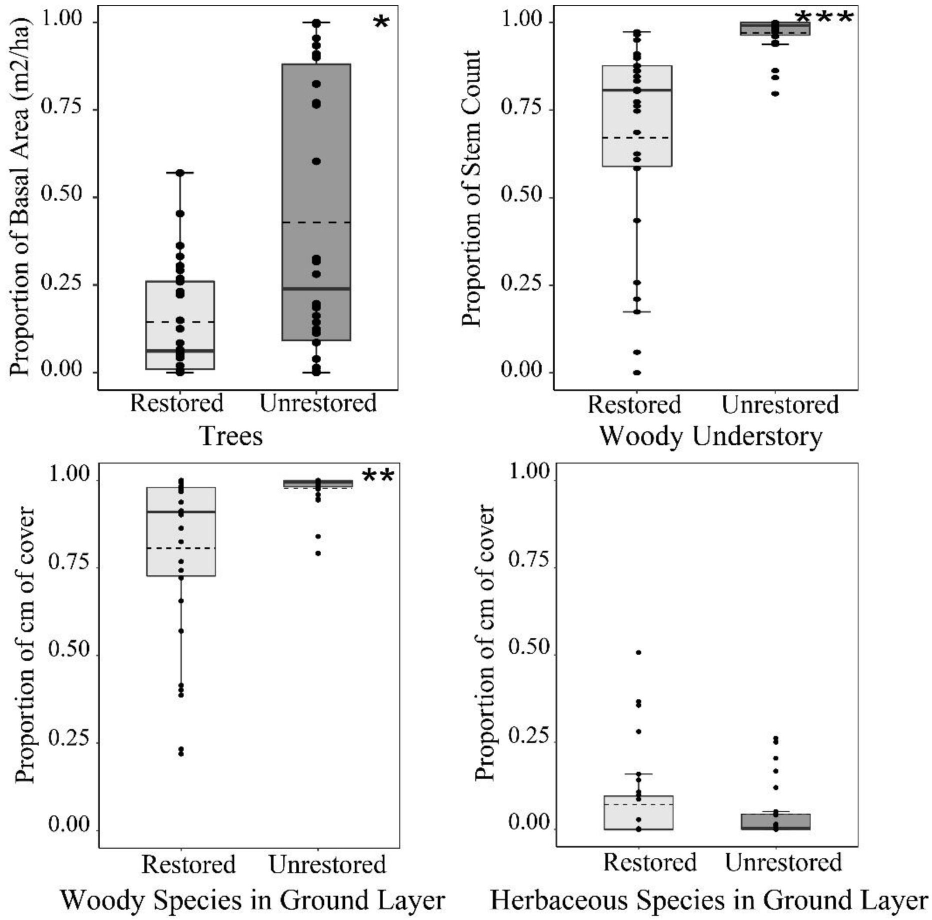

Figure 20. Relative abundance of endozoochoric species in forest stratum communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

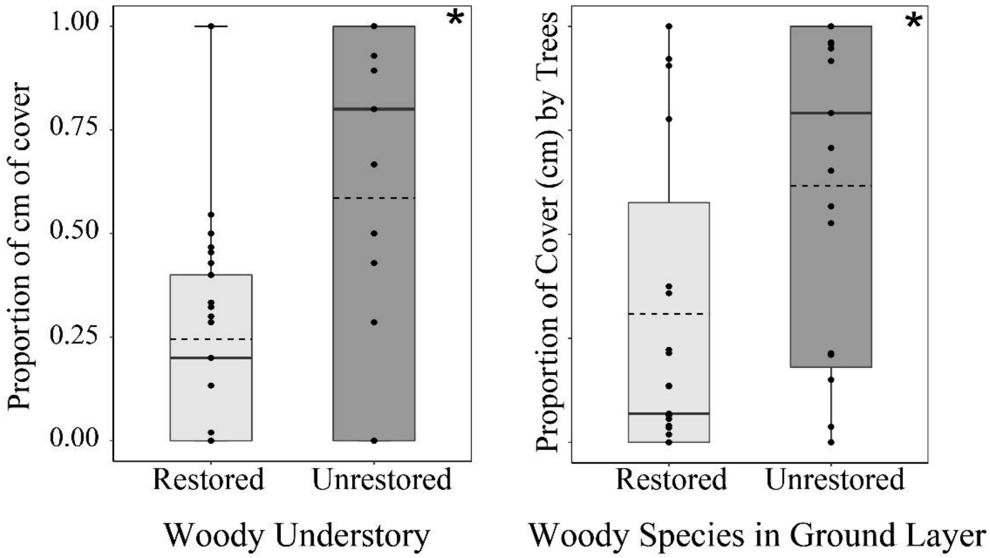

Figure 21. Relative abundance of endozoochoric tree saplings (left) and tree seedlings (right) in woody understory and ground layer communities in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.4 Exozoochory

Exozoochory was only found in herbaceous species in the ground layer. Restored plots had more proportional cover by exozoochoric herbaceous species than unrestored plots (see Figure 22). The most dominant exozoochoric species in both plot types was *Circaea lutetiana*. However, *C. lutetiana* had over double the centimeters of cover in restored plots, with 4385 cm, than in unrestored plots, where it only had 1775 cm of cover (see Table A.58).

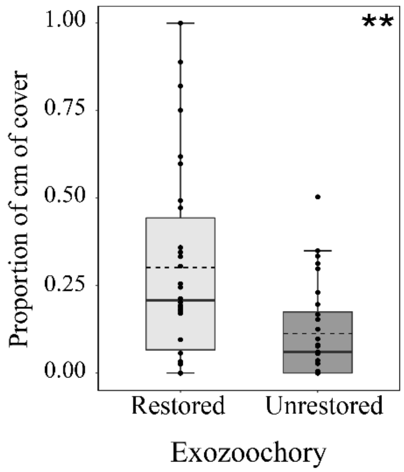

Figure 22. Relative abundance of herbaceous exozoochoric species in ground layer communities of restored (n=30) and unrestored (n=30) plots. Exozoochory was only found among herbaceous species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.5 Seed hoarding

Dispersal by seed hoarding was only found in tree species. There were significant differences in the relative abundance of species dispersed by seed hoarding between restored and unrestored plots.

3.1.6.2.4 Seed Hoarded Trees

Restored plots had a greater relative abundance of trees dispersed by seed hoarding than unrestored plots (see Figure 23). While the most abundant seed hoarded species in restored and unrestored plots was *Carya cordiformis*, *C. cordiformis* in restored plots had over ten times the total basal area than in unrestored plots (see Table A.8).

3.1.6.2.4 Seed Hoarded Species in the Woody Understory

There was a significantly greater relative abundance of species dispersed by seed hoarding in the woody understory of restored plots (see Figure 23). In restored plots, the most abundant species dispersed by seed hoarding was *Carya cordiformis,* followed by *Quercus rubra* (see Table A.23). The most abundant species dispersed by seed hoarding in unrestored plots was also *C. cordiformis,* however *C. cordiformis* in restored plots had eight times the number of stems than in unrestored plots (see Table A.23). The proportion of stems belonging to seed hoarded tree saplings was not different between restored and unrestored plots (see Figure 24).

3.1.6.2.4 Seed Hoarded Species in the Ground Layer

The relative abundance of species dispersed by seed hoarding in the ground layer was not different between restored and unrestored plots (see Figure 23). There was also no significant difference in the relative abundance of tree seedlings dispersed by seed hoarding between restored and unrestored plots (see Figure 24).

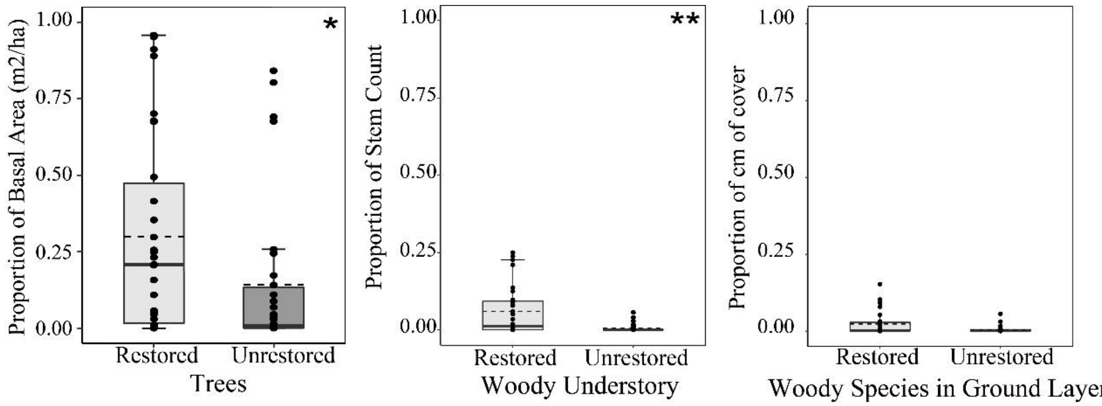

Figure 23. Relative abundance of species dispersed by seed hoarding in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Dispersal by seed hoarding was only found among tree species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

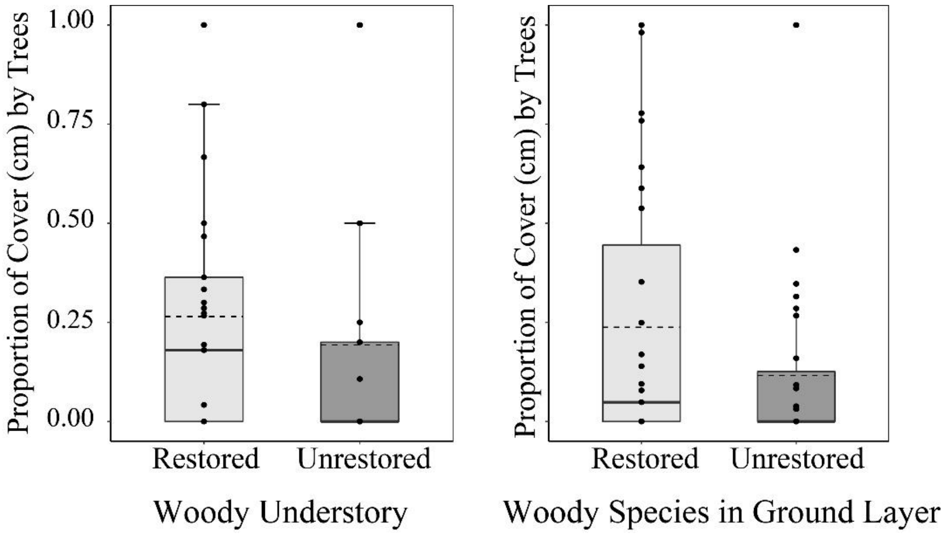

Figure 24. Relative abundance of tree saplings and tree seedlings dispersed by seed hoarding species in woody understory and ground layer communities of restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.6 Ant Dispersal

The proportion of cover by species dispersed by ants was not significantly different between restored and unrestored plots (see Figure 25). Species dispersed by ants were only found in woody species in the ground layer, with the only species being *Vinca minor* (see also Table A.39).

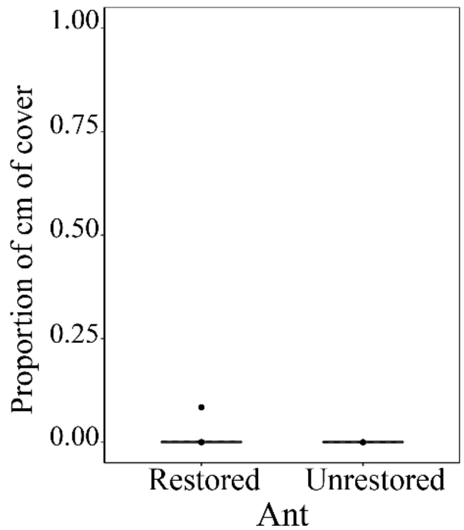

Figure 25. Relative abundance of herbaceous species dispersed by ants in ground layer communities of restored (n=30) and unrestored (n=30) plots. Ant dispersal was only found among herbaceous species. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.6.7 Other Modes of Seed Dispersal

Woody and herbaceous species in the ground layer with other dispersal modes did not have significantly different proportions of cover between restored and unrestored plots (see Figure 26). Other modes of seed dispersal, which consisted of water dispersal and dispersal by launching, were only found in the ground layer and were relatively rare among species in the ground layer (see Tables A.40 and A.59).

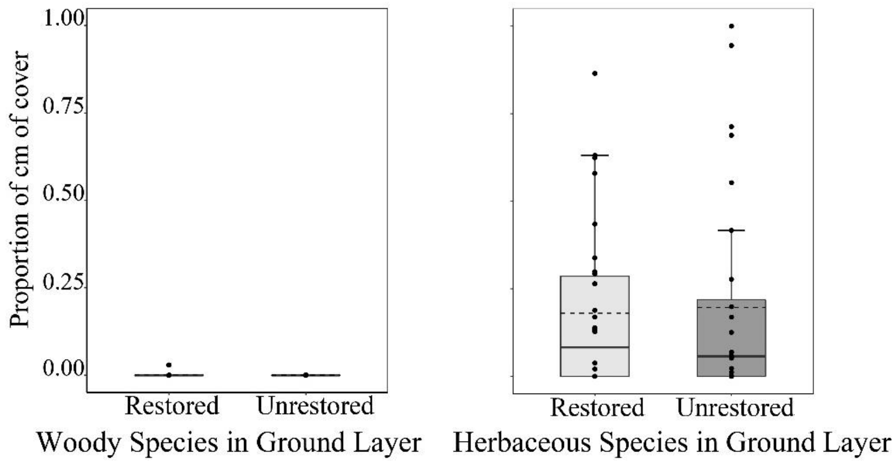

Figure 26. Relative abundance of species with other dispersal modes in ground layer communities of restored (n=30) and unrestored (n=30) plots. Other dispersal modes included dispersal by water and launching. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7 Pollination Syndrome

Pollination syndrome significantly differed between restored and unrestored plots. There were also differences in abundant abiotic and biotically pollinated species between restored and unrestored plots.

3.1.7.1 Trees by Pollination Syndrome

In restored plots, there was a greater relative abundance of trees with abiotic pollination (see Figure 27). Unrestored plots had greater proportions of biotically pollinated trees (see Figure 27). Median proportion of abiotically pollinated trees in restored plots was three times greater than unrestored plots (see Table A.65).

The most abundant tree in restored plots with abiotic pollination was *Fraxinus pennsylvanica*, which had over three times the basal area of the most abundant abiotically pollinated tree in unrest restored plots, *C. cordiformis* (see Table A.9). For biotically pollinated trees, the most abundant species in restored plots was *Prunus serotina* while in unrestored plots it was *Sassafras albidum*.

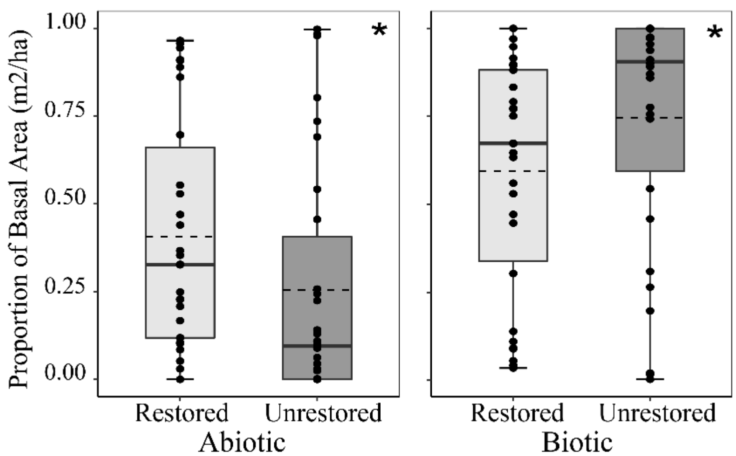

Figure 27. Relative abundance of trees by pollination in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7.2 Species in the Woody Understory by Pollination Syndrome

The relative abundance of species with abiotic pollination in the woody understory was significantly greater in restored plots than unrestored plots (see Figure 28). Conversely, unrestored plots had a significantly greater relative abundance of biotically pollinated species in the woody understory (see Figure 28). Restored and unrestored plots had similar relative abundances of abiotically pollinated tree species in the woody understory (see Figure 29).

In unrestored plots, the most abundant biotically pollinated species was *Rosa multiflora*, which had over three times more stems than the most abundant biotically pollinated species in restored plots, *Lindera benzoin* (see Table A.25). Unrestored plots also had a greater relative abundance of biotically pollinated tree saplings in the woody understory (see Figure 29).

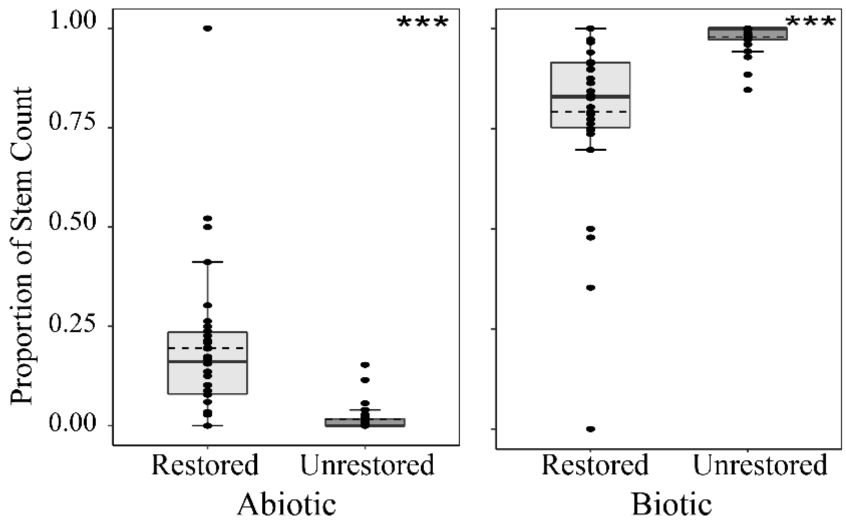

Figure 28. Woody understory stems by pollination syndrome in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

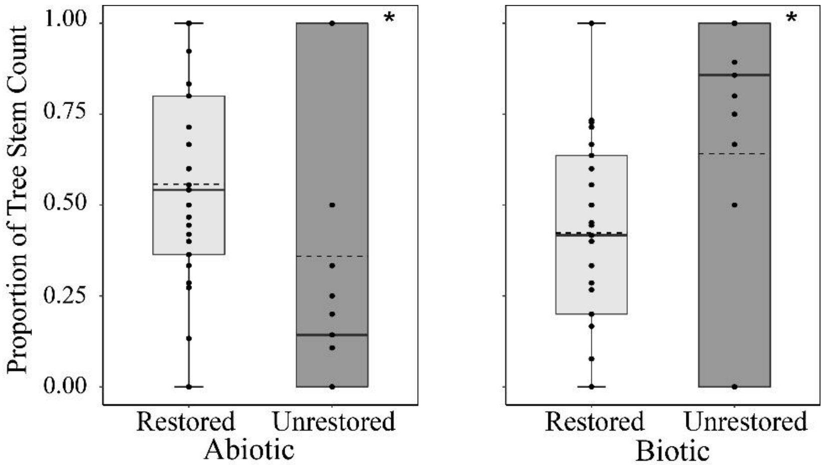

Figure 29. Tree saplings in the woody understory by pollination syndrome in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7.3 Woody Species in the Ground Layer by Pollination Syndrome

Woody species with abiotic pollination in the ground layer had significantly greater relative abundance in restored plots (see Figure 30). There was a significantly lower relative abundance of woody species with biotic pollination in restored plots (see Figure 30). Relative abundances of abiotically and biotically pollinated tree seedlings in the ground layer were not significantly different between restored and unrestored plots (see Figure 31). Of the woody species with abiotic pollination, 14 of the 16 species were tree species (see Table A.41).

The two most abundant biotically pollinated woody species in the ground layer of unrestored plots was *Rosa multiflora* and *Ampelopsis brevipedunculata*. These two species each had over six times the amount of cover than the two most abundant biotically pollinated woody species in restored plots, *Toxicodendron radicans* and *Parthenocissus quinquefolia* (see Tables A.42).

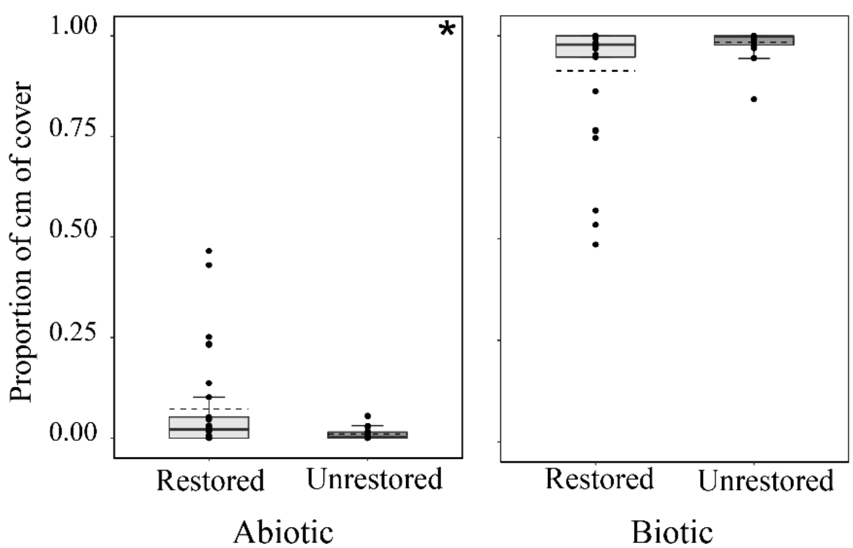

Figure 30. Woody species cover by pollination syndrome in the ground layer of restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

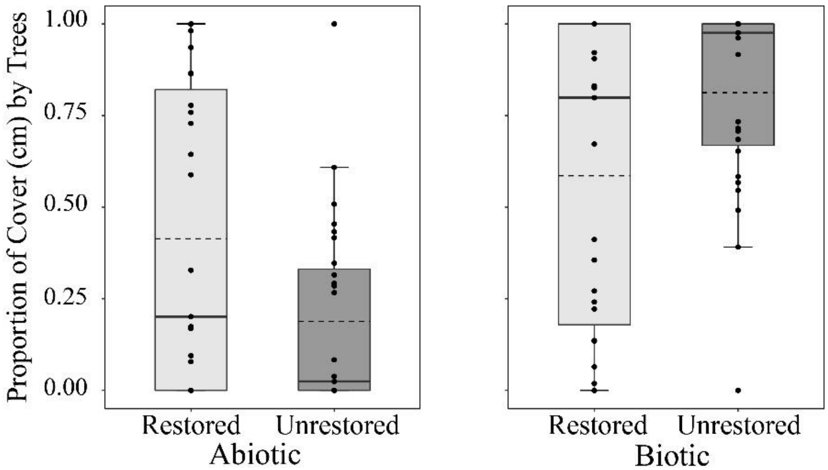

Figure 31. Tree seedling cover by pollination syndrome in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7.4 Herbaceous Species in the Ground Layer by Pollination Syndrome

There was a greater relative abundance of herbaceous species with abiotic pollination in the ground layer of unrestored plots (see Figure 32). The relative abundance of herbaceous species with biotic pollination in the woody understory was similar between restored and unrestored plots (see Figure 32).

In unrestored plots, the most abundant herbaceous species with abiotic pollination was *Artemisia vulgaris* with 2819 cm of cover. In comparison, the most abundant abiotically pollinated herbaceous species in restored plots was *Laportea canadensis*, which only had 289 cm of cover. Abiotically pollinated herbaceous species were not present in the majority of restored or unrestored plots (see Table A.65).

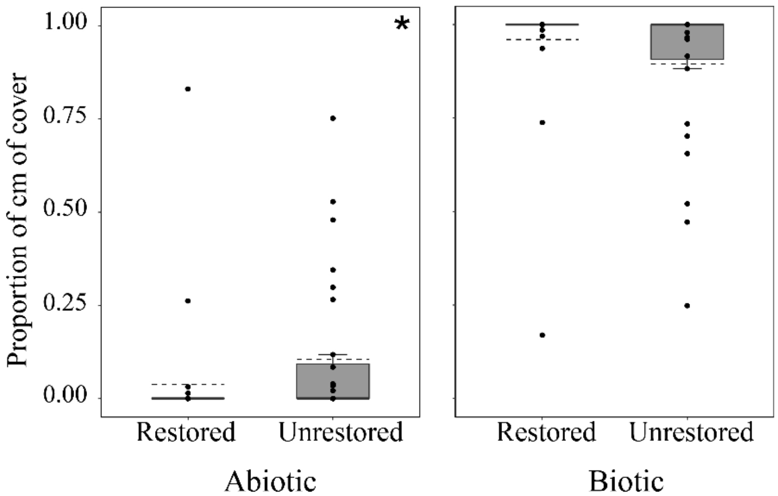

Figure 32. Herbaceous species cover by pollination syndrome in the ground layer of restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.8 Tree Lifespan

There were only significant differences in tree lifespan in the woody understory communities of restored and unrestored plots.

3.1.7.4 Trees by Tree Lifespan

There was no significant difference in the relative abundance of trees with long, moderate, or short lifespans (see Figure 33).

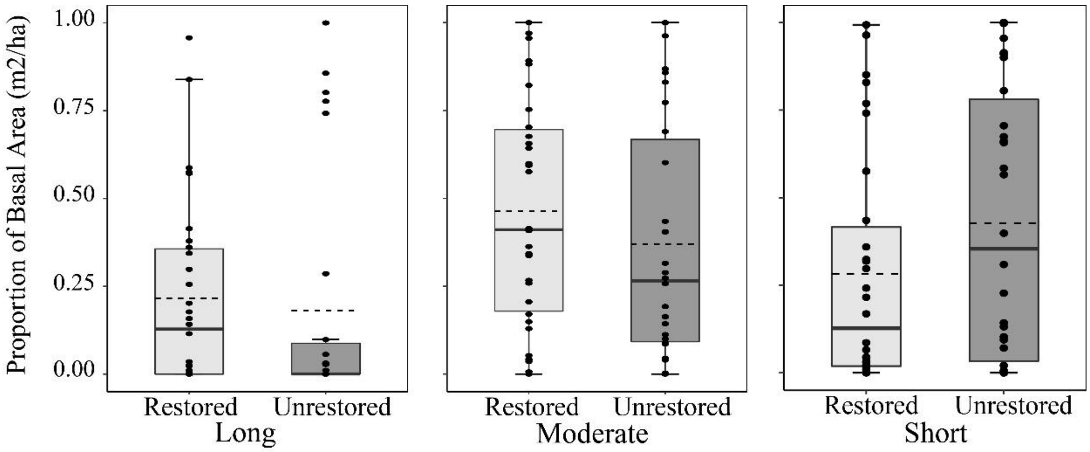

Figure 33. Trees by lifespan in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7.4 Tree Saplings in the Woody Understory by Tree Lifespan

The relative abundance of tree saplings with long lifespans was significantly greater in the restored plots woody understory (see Figure 34). In total, there were only 3 tree species in the woody understory with long lifespans (see Table A.26). Unrestored plots only had one tree species with long lifespan in the woody understory, which was *Acer saccharum* (see Table A.26).

Unrestored plots had a significantly greater tree sapling relative abundance with short lifespans than restored plots (see Figure 34). There was no significant difference in the relative abundance of tree saplings with moderate lifespans between restored and unrestored plots (see Figure 34).

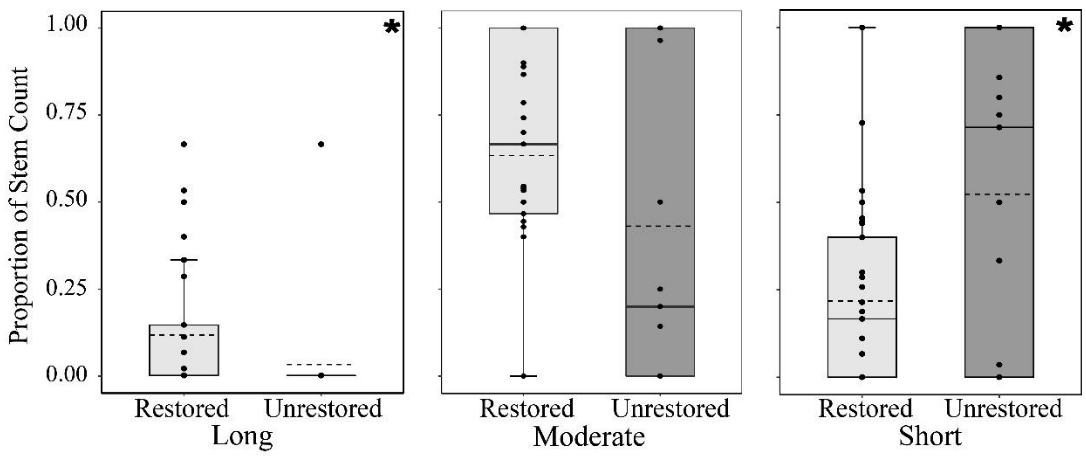

Figure 34. Tree saplings in the woody understory by tree lifespan in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.1.7.4 Tree Seedlings in the Ground Layer by Tree Lifespan

Tree seedlings with long, moderate, and short lifespans in the ground layer did not have different relative abundances between restored and unrestored plots (see Figure 35).

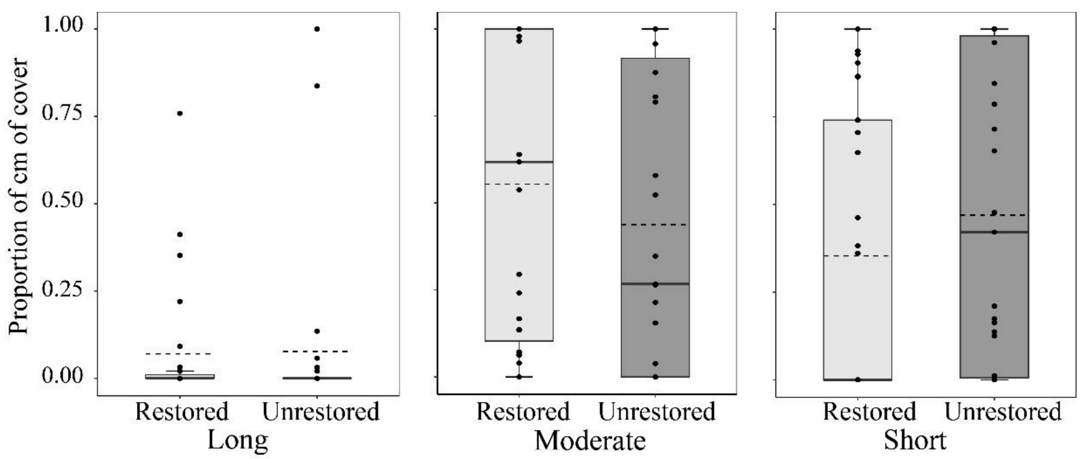

Figure 35. Tree seedling cover by tree lifespan in restored (n=30) and unrestored (n=30) plots. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.2 Functional Diversity

Functional evenness was the only diversity index that was significantly different between restored and unrestored plots. Other indices did not have statistical differences between restored and unrestored plots.

3.2.1 Functional Richness

Restored and unrestored plots did not differ in functional richness in both the combined trees and species in the woody understory (see Figure 36). There was also no significant difference in functional richness between the ground layers of restored and unrestored plots (see Figure 36).

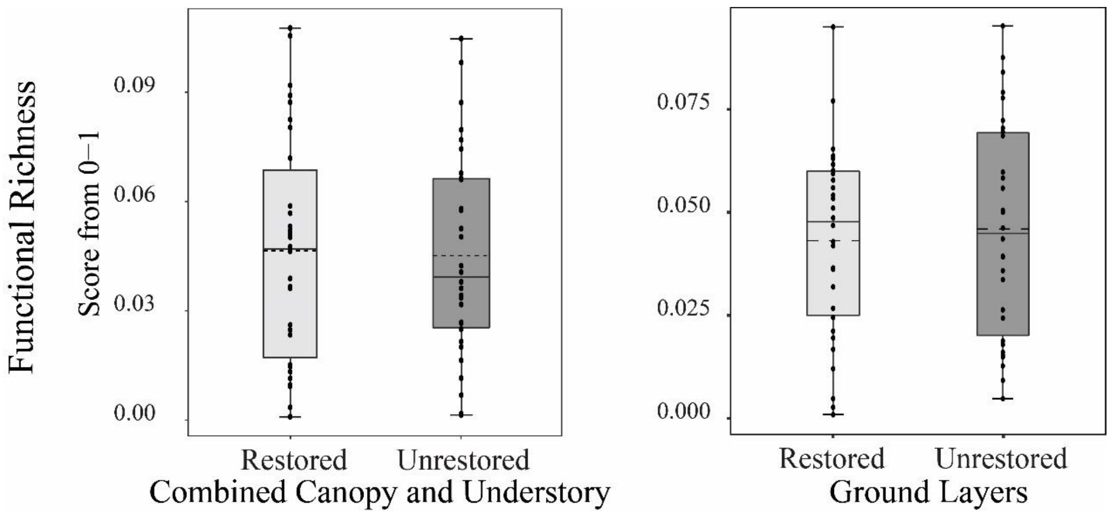

Figure 36. Functional richness of forest strata in restored (n=30) and unrestored (n=30) plots. Functional richness was calculated using the dbfd() function in the R package, "FD". Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.2.2 Functional Evenness

Functional evenness was higher in the combined trees and species in the woody understory (see Figure 37). In the ground layer, restored plots also had higher functional evenness than unrestored plots (see Figure 37).

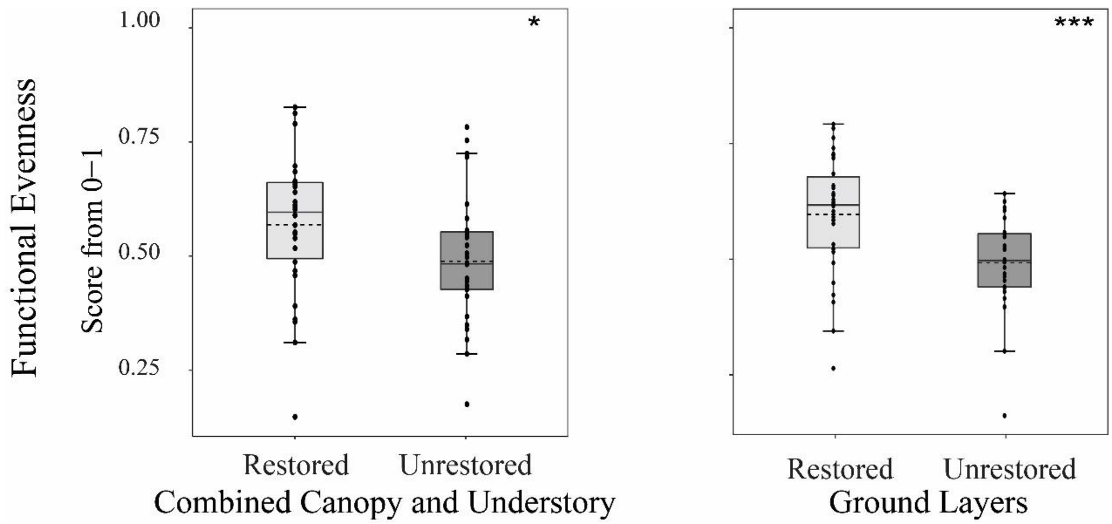

Figure 37. Functional evenness of forest strata in restored (n=30) and unrestored (n=30) plots. Functional evenness was calculated using the dbfd() function in the R package, “FD”. Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

3.2.3 Functional Divergence

Combined trees and species in the woody understory did not have different functional divergence scores between restored and unrestored plots (see Figure 38). Functional divergence scores in the ground layer did not differ between restored and unrestored plots (see Figure 38).

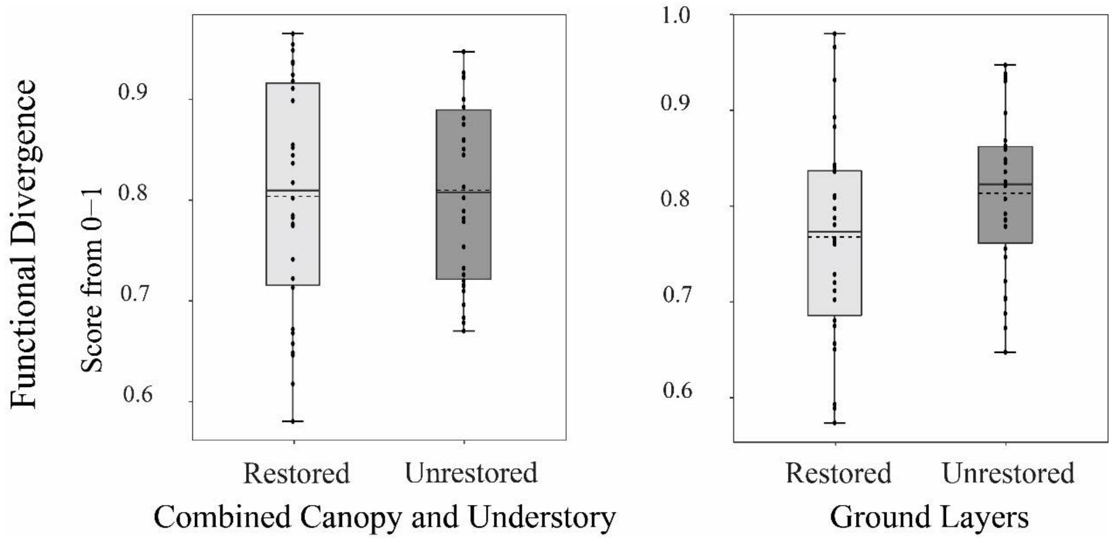

Figure 38. Functional divergence of forest strata in restored (n=30) and unrestored (n=30) plots. Functional divergence was calculated using the dbfd() function in the R package, "FD". Asterisks indicate analyses with significant differences (Mann-Whitney U Test, * = P < 0.5, ** = P < 0.01, *** = P < 0.005). Points outside of whiskers indicate outliers. Solid horizontal lines indicate the median of all samples and dashed lines indicate the mean of all samples.

4. Discussion

Ecological restoration, forest vegetation dynamics, and urban influences drove the trends found in functional composition and diversity in urban forest patches. Each driver of change influenced some traits more than others. Trends observed in this study indicate that restoration was successful in redirecting ecological succession in restored plots and restoration goals were met.

4.1 Functional Trait Composition

Ecological restoration, forest vegetation dynamics, and urban ecosystems drove functional composition and diversity in urban forest patches. Restoration methods clearly drove functional trait composition trends in tree communities of restored plots, particularly in seed dispersal, pollination, and maximum tree height. In the woody understory, restoration drove differences in growth form. Forest vegetation dynamics also drove trends in seed dispersal and shade tolerance in the woody understory and ground layer of restored plots. It also drove trends in tree lifespan in urban forest patches. Urban conditions drove trends in seed dispersal and growth form. Interaction between drivers drove functional trait composition trends in the ground layer. In the woody understory, trends in shade tolerance, maximum tree height, seed dispersal, seed mass, and pollination were driven by interactions among the three drivers.

4.1.1 Effects of Ecological Restoration

Ecological restoration drove growth form trends seen in restored plots woody understories. Removal of target invasive vine species during restoration resulted in the lower relative abundance of vines species in the woody understory. The dominance of mostly native shrub species in restored plots indicates the success of ecological restoration in lowering the regeneration of target invasive species. There were also less shrub species stems overall in restored plots, driven by target invasive shrub species removal.

Restoration methods used during initial restoration resulted in trends of shade tolerance in restored urban forest patches. Tree plantings during restoration drove greater relative abundances of shade tolerant trees in restored plots. Dominant shade tolerant species in restored plots, such as *Fraxinus pennsylvanica* and *Acer saccharum*, were among species planted (Johnson and Handel 2016). While proportions of intermediate shade tolerant trees were similar between restored and unrestored plots, the frequent planting of *Quercus rubra* and *Acer rubrum* during restoration (Johnson and Handel 2016) may have been the driving force behind the large total basal area of intermediate shade tolerant trees.

Tree plantings also resulted in restored plots having a greater average maximum tree height than unrestored plots amongst trees. High light conditions in unrestored canopies and during initial restoration should have favored shorter species (Lambers, Chapin, and Pons 1998; Finegan 1984; Peña-Claros 2003). However, in restored plots, planted species like *Liriodendron tulipifera* (tulip poplar), *Carya cordiformis* (bitternut hickory), and *Quercus rubra* (red oak) increased the average maximum tree height in trees.

Seed dispersal modes found among trees and woody understory in restored plots were driven by methods used during initial restoration. The greater proportions of seed hoarded trees in restored plots were driven by oak and hickory species. Oaks were commonly planted during restoration, thus their dominance in the tree community was expected. However, the high relative abundance of *Carya cordiformis* was not as expected due to low planting frequency during restoration (Johnson and Handel 2016). Something that may be driving this trend are populations of rodent species, a group known to spread seeds via hoarding and have higher populations in urban areas (Hein, 1997; Gliwicz *et al*., 1994). While seeds of *C. cordiformis* may be spread by rodent species, tannin levels in the seeds may discourage mammals from consuming the seed and possibly increase the chances for germination.

Removal of target invasive species drove the lower relative abundance of endozoochoric species in the woody understory and ground layer. Significant dominance by *Rosa multiflora* was the primary driver of greater endo-zoochoric woody species stems and cover in unrestored plots. In addition, unrestored plots were dominated by other endo-zoochorus, non-native shrub and vine species like *Ampelopsis brevipedunculata, Lonicera japonica,* and *Celastrus orbiculatus*. These are traits identified to be successful invaders in urban areas (Aronson *et al*., 2007; McCay *et al*., 2009). Taking these species out of restored plots would then lower the relative abundance of endozoochoric species.

In the ground layer, removal of target invasive species in restored plots drove a greater relative abundance of herbaceous exozoochoric species. The removal of dense invasive shrub and vine cover during restoration, increased the amount of open space (Bounds *et al*., 2005; Johnson and Handel, 2016). This increase in space would have allowed non-flying animals to move about the urban forest patch without much obstruction. An increase in moving dispersers to latch on to would favor plants dispersed via exozoochory.

Lack of target invasive species removal in unrestored plots led to the greater relative abundance of herbaceous ground layer species with unassisted seed dispersal. This trend was also driven by the greater presence of *Allaria petiolata* in unrestored plots. In the unrestored ground layer where there is little room, it may be advantageous to have unassisted seed dispersal and have seeds fall relatively close by where conditions may be favorable (Howe and Miriti, 2004).

Tree planting during initial restoration in restored plots drove a greater proportion of trees with abiotic pollination. Species planted during restoration included a number of wind pollinated species, like *Quercus spp.* (Johnson and Handel 2016; Bounds et al. 2014), because restoration aimed to set successional trajectories towards that of regional oak-hickory forests. Unrestored plots were noted to have more open canopies than restored plots (Simpson and Johnson 2019). This open canopy in unrestored plots would favor biotically pollinated trees because it provides ideal conditions for pollinator species (Taki et al. 2013; Hanula, Ulyshen, and Horn 2016).

4.1.2 Effects of Forest Vegetation Dynamics

The changes in successional trajectory towards one similar to regional forests has influenced the functional composition observed in restored plots. Since the removal of target invasive species and planting of trees, the successional trajectory of restored plots resembled the native forest structure more (Johnson and Handel 2016).

Shade tolerance is a clear indicator of how succession in restored plots has affected functional composition. The greater presence of shade tolerant invasive species in the woody understory, like *Lonicera japonica* and *Celastrus orbiculatus*, were a reason why unrestored plots had greater relative abundances of shade tolerant species. While the top of the understory in unrestored plots is exposed to high levels of light, light underneath the dense shrub and vine layer is extremely low (Simpson and Johnson 2019). The low light levels underneath the shrub layer is likely why there was a difference, because low light levels tend to favor shade tolerant species (Canham et al. 1994; Morin 1999; Glitzenstein, Harcombe, and Streng 1986).

In the ground layer, restored and unrestored plots were both shaded (Simpson and Johnson 2019), creating an environment where shade tolerant species could be equally favored in both plot types. These similar conditions explain the lack of difference in woody species in the ground layer by shade tolerant species. Greater proportional cover by intermediate shade tolerant species in restored plots could be a sign of changing light conditions under the canopy towards lower light conditions, as there were a greater number of intermediate shade tolerant tree species. Shade underneath the *Rosa multiflora* in unrestored plots may be denser than in restored plots, driving the greater abundance of shade tolerant herbaceous species in the ground layer. In restored plots, greater proportional cover by intermediate shade tolerant herbaceous species may indicate that ecological succession in restored plots is moving towards a more shaded condition, but still in earlier stages of succession. The lack of difference in cover from shade intolerant herbaceous species is likely due to the shaded conditions present in the ground layer, as such conditions do not favor shade intolerant species (Canham et al., 1994; Morin, 1999; Glitzenstein et al., 1986).

Influences from these changing light levels were observed with the greater proportion of intermediate shade tolerant tree stems, and woody and herbaceous species with intermediate shade tolerance in the ground layer. This indicates a shift towards a more shaded environment. Johnson and Handel (2016) noted that restored plots were relatively young, which explains why the abundance of shade tolerant species was not high in restored plots. Future analyses of functional traits in these urban forest patches at later time points would determine if restored plots continue to follow successional trajectories similar to regional forests.

Similar light conditions at the time of initial restoration and in the canopy of unrestored plots resulted in the similar average SLA between the tree communities. Being exposed to similar conditions, the trees are being filtered to favor similar traits (Morin, 1999; Williams *et al*., 2015; Aronson *et al*., 2017). Shaded conditions in the ground layer of both plot types is the driver of similar average SLA in herbaceous species in the ground layer.

The larger presence of early successional species in both restored and unrestored plots is what drove similar average maximum tree height of tree sapling communities in woody understories. *Fraxinus ameriana* was the most abundant tree species in the woody understory of restored plots while *Sassafras albidum* was the most abundant in unrestored plots. These two species had similar average maximum tree heights (24.4 m and 22.4 m respectively) and is a reason for seeing similar average maximum tree height between restored and unrestored plots woody understories.

While greater proportional basal area of trees in restored plots was likely influenced by direct planting of tree species, the larger proportion of stems by seed hoarded trees in the woody understory reflects trends in seed dispersal modes found in forests with mature trees (Finegan 1984; Körner 2005). Tree species recorded in the woody understory were stems under 1 m tall and DBH less than 2.54 cm, too young to be planted 15-20 years prior, reflecting the potential canopy in urban forest patches.

High light conditions in the woody understory of unrestored plots drove a greater abundance of biotically pollinated species. In unrestored plots, the woody understory was exposed to high light from the lack of a closed canopy (Simpson and Johnson 2019). These conditions create favorable environments for pollinators (Taki *et al*., 2013; Hanula *et al*., 2016), favoring species with biotic pollination.

4.1.3 Effects of Urban Ecosystems

Urban forest patches used in this study are nested within the larger urban ecosystem, being affected and influenced by conditions inherent to urban ecosystems. The way urban forest patch functional composition was driven by urban conditions in this study was illustrated by the differences in seed dispersal methods in combination with growth form. Non-native species that thrive in urban ecosystems tend to be shrub and vine species with endo-zoochory (Aronson, Handel, and Clemants 2007). Unrestored plots, dominated by invasive shrubs and vines, demonstrated this trend in the woody understory. Many of these plots were dominated by *Rosa multiflora* and/or *Ampelopsis brevipedunculata*, both of which were target invasive species.

Successful native species in urban ecosystems tend tree species are wind dispersed or dispersed by hoarding (Aronson, Handel, and Clemants 2007). This trend was observed in woody understory communities of restored plots. Seed hoarding was primarily driven by the greater tree presence in the understory because only tree species in this layer had this dispersal mode. Species wise, restored plots had oaks and hickories as dominant species. This indicates successful regeneration of these native nut-bearing species, a trait that favors native trees in urban environments (Aronson et al., 2007). In unrestored plots, the dominant species was C. cordiformis. However, presence was low in overall as it only had 9 stems and made up under 1% of total stems in the woody understory.

4.1.4 Effects of Interacting Drivers

Drivers in this study system also interacted with each other, resulting in these interactions driving trends in functional trait composition of urban forest patches. The removal of target invasive species, at the time of initial restoration, influenced site availability for other species by increasing the amount of open ground (Johnson and Handel 2016) in restored plots. This made it possible for other species to regenerate in the ground layer. In restored plots there was a greater relative abundance of tree species in the ground layer, indicating greater regeneration of trees. Regeneration of tree species driven by the effects of increased space availability due to target invasive species removal was also seen in the woody understory. Though the relative abundance of shrubs in the woody understory and ground layer of restored plots did not differ, this interaction altered the most abundant shrub species in restored plots. *Rosa multiflora* was the dominant shrub in both plot types, but had significantly less total cover and was co-dominant with *Lindera benzoin* in restored plots.

There was also a difference in abundant vine species in the ground layer of restored plots driven by the interaction of restoration and forest vegetation dynamics. Vines in the ground layer of restored plots were primarily the native species *Toxicodendron radicans*, which was present in 80 percent of restored plots and 3758 cm of cover, along with *Parthenocissus quinquefolia,* which was also present in 80 percent of restored plots and had 2915 cm of cover. This is a stark contrast from unrestored plots were the most abundant vine in the ground layer was target invasive species, *Ampelopsis brevipedunculata,* present in 80 percent of plots and made up 19 percent of total ground cover. Difference in abundant species between plot types indicates that ecological restoration was successful in lowering the regeneration of target invasive vine species. Having less ground cover by target invasive species (Johnson and Handel 2016) also drove an increase in perennial species in the ground layer of restored plots.

Removal of target invasive species, resulting in increased open ground drove trends seen in shade tolerance. The dominance of native intermediate shade tolerant species, *Lindera benzoin*, in restored woody understories indicates that ecological restoration was successful in lowering the abundance and regeneration of *Ampelopsis brevipedunculata*, an intermediate shade tolerant species. *A. brevipedunculata* was a target invasive species removed during initial restoration, which resulted in more room for other species to regenerate in its place.

The removal of target invasive species in restored plots led to more space for species to regenerate (Johnson and Handel 2016), but it also led to closing canopies where there was less light reaching the understory (Simpson and Johnson 2019). Greater ground cover by shade intolerant woody species in unrestored plots was driven by the dominance of *Rosa multiflora*, which was present in 97 percent of unrestored plots and had 30,408 cm of cover. Cover by *R. multiflora* was so dense that it was found dominant in the woody understory and ground layer of unrestored plots. *R. multiflora* was also a target invasive species removed during initial restoration. The combination of removing *R. multiflora* and closing canopy not only led to less cover of this species, but a change in most abundant shade tolerant species. In the ground layer of restored plots, the co-dominant shade intolerant woody species were *Prunus serotina*, with 349 cm of cover over 57 percent of restored plots, and *R. multiflora*, with 1527 cm of cover over 53 percent of plots. Less cover by shade intolerant invasive species, such as *R. multiflora*, in restored plots also indicates that ecological restoration was successful in suppressing the regeneration of these species by closing the canopy.

Results of average seed mass in the tree community supported the hypothesis that seed mass would be similar between restored and unrestored plots. This was expected because trees in both plot types were exposed and grew in high light levels. Being exposed to similar environmental conditions would then favor individuals with similar traits (Morin, 1999; Williams *et al*., 2015; Aronson *et al*., 2017). Though high light levels tend to favor species with lighter seeds (Wilfahrt, Collins, and White 2014; Körner 2005; Navas et al. 2010; Muscarella et al. 2016), trees in both plots had species with large seed masses. In restored plots, this was driven by species planted during initial restoration. Species that affected this were oaks (*Quercus spp.*) and hickories (*Carya spp.*). Oak species were commonly planted during the restoration project amongst other species (Johnson and Handel 2016). However, species like *Carya cordiformis* were not as frequently planted and was a species commonly found in both restored (present in 40%) and unrestored plots (present in 30%). This may be driven by the lack of seed consumption by predators, giving seeds of this species a greater chance of germinating.

In the woody understory, the removal of target invasive species that led to the increase in tree regeneration drove the average seed mass to be greater in woody understory communities in restored plots. It is clear that the difference was driven by the greater presence of trees in restored understories as seen from the growth form analyses. Greater average seed mass of woody species in the ground layer of restored plots was also driven by the larger presence of trees. Tree species tend to have larger seed masses than shrubs (Moles et al. 2005), thus a greater presence in trees may drive an increase the average seed mass in a community.

The greater regeneration of trees in restored plots driven by increased space by target species removal in restored plots, also drove a greater average SLA for woody understory communities in restored plots. Tree species tended to have larger SLA than the shrubs and lianas in this system. Though there were more tree seedlings in the ground layer of restored plots, lower proportional cover of trees in the ground layers overall drove average SLA of woody communities to not differ between restored and unrestored plots.

In general, trees found in the ground layer were early successional species that had similar maximum plant heights. In restored plots, this could mean that early successional species are able to regenerate more with the open ground. Dominance of *Sassafras albidum*, a highly clonal species, in the ground layer of unrestored plots may be due to a large number of *S. albidum* clones from individuals found in other forest strata. This could explain how this shade intolerant species was so dominant in unrestored plot ground layers containing extremely shaded conditions.

Ecological restoration exposed the ground layer to high light and increase ground space created conditions where early successional species may germinate (Finegan, 1984; Howe and Miriti, 2004). This drove greater relative abundances in wind dispersed species and species dispersed by seed hoarding in restored plots Greater proportional cover by wind dispersed woody species in the ground layer of restored plots was driven primarily by the greater tree presence in the ground layer. It also means that wind dispersed, early successional tree species are successfully regenerating in the ground layer, indicating successful trajectory towards the restoration project goal to increase tree regeneration. The open ground increased the chance of wind dispersed seed to reach the soil and germinate, acting as pioneer trees (Howe and Miriti, 2004).

In restored plots, the greater relative abundance of abiotically pollinated woody species in the ground layer was driven by the greater cover by tree seedlings. The proportion of biotically pollinated woody species in the ground layer was similar in restored and unrestored plots. Because most of the ground layer in both plot types were covered in shrubs and vines, it makes sense as to why there was a lack of difference. However, the most abundant biotically pollinated species in the ground layer were different between restored and unrestored plots. This was driven by the removal of target invasive species, which in turn provided the opportunity for other species to regenerate in the ground layer. Restored plots were dominated primarily by native species, *Toxicodendron radicans* and *Parthenocissus quinquefolia*, while unrestored plots were severely dominated by target invasive species, *Rosa multiflora* and *Ampelopsis brevipedunculata*. Total cover by shrubs and vines was also lower in restored plots.

Other trends were influenced by the low abundance of species possessing a particular trait state. Graminoids were only found in the ground layer of unrestored plots, which may be due to sparse distribution and low abundance. In the case of biennials in the ground layer, lower proportional cover by biennials in restored plots was due to less cover by *Allaria petiolata*. Herbaceous species tend to have very light seed masses and is the likely reason for the lack of difference seen in the average seed mass of herbaceous ground layer species cover between restored and unrestored plots. This was reflected in the results as restored plots had a median average seed mass of 4 mg while unrestored plots had a median average of 2.6 mg.

Greater proportion of tree sapling stems in the woody understory of restored plots also drove the greater relative abundance of long-lived tree species found in restored plots. The low number of unrestored plots with tree species in the woody understory is an influence on these results as well. Where there were trees, unrestored plots had greater proportions of trees with short lifespan. The species driving this was *S. albidum* which occurred in 37% of the unrestored plots. Restored plots had 9 species with short lifespans, however their stem count and presence throughout restored plots was low. Relative abundance of tree species in the woody understory, driven by the interactions of ecological restoration methods on site conditions, greatly influenced trends of functional traits in restored plots.

4.2 Functional Diversity

Ecological restoration drove greater functional evenness in restored plots, which was driven by the removal of few dominant target invasive species making room for other species to grow. The lack of difference in functional richness and functional divergence was driven by similar conditions present in restored and unrestored plots.

4.2.1 Functional Richness

Functional richness is a trait that is correlated to species richness (Villéger, Mason, and Mouillot 2008). Noted in Johnson and Handel (2016), species richness was not different between restored and unrestored plots. This would explain why restored and unrestored plots did not differ in functional richness scores. This may change as ecological succession in these urban forest patches continues.

Lack of difference in functional richness indicates that restored plots and unrestored plots are filling in a similar number of niches in their community (Mason et al. 2005). However, I did not use a null model in this study to test whether my calculated functional diversity indices were higher or lower than expected (Bello 2012). Running null models on data in this study may reveal whether these plots were more or less functionally rich than expected due to influences not identified in this study.

4.2.2 Functional Evenness

Functional evenness is related to species abundance in a community (Villéger, Mason, and Mouillot 2008), it was expected that functional evenness would differ between restored and unrestored plots and finding in this study support this hypothesis. Unrestored plots, while similar in species richness to restored plots, differed in species abundance (Johnson and Handel 2016) because few target invasive species were highly dominant. The removal of the few dominant target invasive species in restored plots created and opportunity for more species to fill in those roles. In each trait analysis, restored plots tended to have more species with similar levels of dominance amongst the most common species. This could also mean that light conditions were more evenly spread throughout the forest strata in restored plots.

Greater functional evenness in restored plots indicates that restored plots have niches filled by multiple species (Díaz and Cabido 2001; Mason et al. 2005). This means that in the case of species loss, there are likely to be other species filling in the same niche, or role, as lost species (Díaz and Cabido 2001; Funk et al. 2008; Mason et al. 2005) and may indicate greater resilience in restored plots.

4.2.3 Functional Divergence

The lack of difference in functional divergence scores between restored and unrestored plots is likely due to the presence of similar conditions found in restored and unrestored plots. Both plots had areas in the forest strata where species were filtered by high light conditions and others where they were filtered by shaded conditions. These were the two extremes of the light spectrum, and created conditions filtered for traits favored at both extremes.

Results may also indicate that species in restored and unrestored plots have similar levels of resource competition. Functional divergence scores indicate whether there is high resource competition or not (Mason et al. 2005). Similar functional divergence scores would then indicate similar levels of resource competition between communities.

4.3 Implications

Ecological restoration is a process that alters environmental conditions and driving species composition by direct changes and by changing successional trajectories (Luken 1990; Palmer, Ambrose, and Poff 2008; McDonald et al. 2016). Understanding which species will be successful based on their functional traits can assist land managers in selecting plants that will establish and regenerate successfully immediately after restoration and during succession. Being informed about the functional traits of invasive species could also aid land managers in planning and creating environmental conditions that would inhibit their growth and regeneration. It may also help identify any potential unwanted species that could invade restored plots as conditions change. In the case of this study, if ecological succession continues to move towards a closed canopy, shaded conditions may favor shade tolerant non-native species.

In urban ecosystems, understanding how urban conditions affect the assembly of species in urban forest patches or other remnant habitats can help land managers create plans that consider these altered conditions. Remnant habitats serve as a potential source and strong hold for urban biodiversity (Kowarik 2011; Angold et al. 2006; Godefroid and Koedam 2003) and understanding how urban conditions select for or against species could assist land managers in increasing and maintaining urban biodiversity in urban forest patches.

Habitat fragments are essential in providing ecosystem services and ecosystem functions in a city (Bolund and Hunhammar 1999; Kowarik 2018; Tyrväinen et al. 2014), and the resilience of habitat patches are important to maintaining and providing further ecosystem services and ecosystem functions (Folke et al. 2004; Andersson et al. 2014; Ahern 2011). Investigating the functional diversity in remnant habitats could assist land managers and city planners in increasing the resilience of these habitats as each of the functional diversity indices used in this study correspond to ecosystem functioning and processes (Díaz and Cabido 2001; Mason et al. 2005). Functional richness may inform land managers of the breadth of ecological niches filled by species in a community (Mason et al. 2005). Functional evenness may provide an indication on whether or not ecosystem processes or functions would be lost in a disturbance due to low numbers of individuals filling in those roles. Finally, functional divergence could help identify areas with low ecosystem function (Mason et al. 2005).

4.4 Future Studies

Moving forward, methods and concepts in this study can be used to inform us about how ecological restoration, forest vegetation dynamics, and urban ecology drive functional composition and diversity over time. Because ecological restoration in this study focused on the regeneration of native trees and removal of invasive species, an analysis investigating the functional composition and diversity of native and non-native species in restored and unrestored plots would be a future study that should be conducted. An analysis between native and non-native plants would show that functional composition and diversity in restored plots from this study was driven by native plants or if the combination of native and non-native plants were the reason for trends observed in this study.

As part of a long-term study investigating effects of ecological restoration in urban forest patches, additional vegetation sampling was performed in 2015 and 2016, giving us another time point to compare to. A study using these data would show how succession has further affected functional composition and diversity in these urban forest patches and if restored plots are continuing on a successional trajectory different from unrestored plots. Between 2010 and 2015, there were a number of natural disasters creating large disturbances. An analysis of functional composition and diversity between 2009 – 10 data and 2015-16 data could identify how these disturbances may alter successional trajectory of urban forest patches. Management data collected by Johnson and Handel (2019) could be used with these data to investigate the effects of different management levels, methods, and intensities on functional composition and diversity in restored plots.

Using vegetation sampling data collected in an urban old growth forest located at New York Botanical Garden (NYBG), a comparison with this dataset, 2009-10, and 2015-16 vegetation sampling data would indicate if restored plots are becoming more similar to old growth urban forests or are on a separate successional trajectory. Urban old growth forest data and trait data for those species could be compared to regional forest species and trait data to study the long-term influences of urban conditions on urban forest patches.

Soil seed bank species data collected by Johnson and Whitehead (2019), could be used to investigate and compare functional traits of species in the soil seed bank and species regenerating in the ground layer. This would aid in understanding what environmental filters are acting on the soil seed bank species and preventing or encouraging the germination of these species.

Data on light conditions in the forest strata of restored and unrestored plots (Simpson and Johnson 2019) could be used to further investigate the effects of light levels at each forest stratum on functional composition and diversity in urban forest patches.

4.5 Conclusion

This study demonstrates that ecological restoration drives changes in the functional composition and diversity of urban forest patches. These shifts have indicated that restoration goals have been met and altered environmental filters have shifted functional trait composition and diversity away from those of unrestored plots after 15-20 years.

Resilience and ecosystem functioning in urban ecosystems are influenced by the functional traits of its organisms and functional diversity of its communities. Restoration can be a tool directing the functional composition and diversity of urban ecosystems. Disturbances common to urban ecosystems and those caused by stronger natural disasters will require future ecological restoration efforts. Because restoration is a long-term process, it will be necessary to continue monitoring, managing, and researching restoration projects to provide information that will inform future restoration and adaptive management decisions. Restoration in urban ecosystems is critical to the ecosystem functioning affecting the health and well-being of over half of the world's population and increasingly important in a time where resilience of cities is important in the face of uncertain change.

Appendices

A.1 Sources of Data from TRY Plant Trait Database

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A.2 Sources of Shade Tolerance

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A.3 Tables of Species by Forest Stratum and Functional Trait

A.3.1 Tree Species

A.1. Trees of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Restored				
Species	**IVI**	**Total Basal Area (m^2/ha)**	**% Basal Area**	**% of Plots**
Prunus serotina	102.5	492.37	10.48	76.67
Robinia pseudoacacia	85.9	1741.19	37.05	40.00
Liriodendron tulipifera	73.3	468.81	9.98	50.00
Fraxinus pennsylvanica	66.7	172.56	3.67	53.33
Carya cordiformis	58.9	593.89	12.64	40.00
Acer saccharum	56.7	84.44	1.80	50.00
Quercus rubra	56.5	306.99	6.53	46.67
Acer rubrum	41.9	189.12	4.02	30.00
Celtis occidentalis	38.5	46.44	0.99	33.33
Ulmus rubra	34.6	61.66	1.31	33.33
Quercus palustris	28.6	173.72	3.70	23.33
Morus alba	25.4	18.74	0.40	23.33
Prunus avium	24.9	2.21	0.05	23.33
Liquidambar styraciflua	23.0	76.24	1.62	20.00
Sassafras albidum	20.9	43.23	0.92	16.67
Betula lenta	18.7	10.03	0.21	16.67
Fraxinus americana	15.2	33.68	0.72	10.00
Fagus grandifolia	10.7	0.47	0.01	10.00
Quercus alba	10.7	12.91	0.27	10.00
Acer saccharinum	10.4	0.62	0.01	10.00
Aesculus hippocastanum	10.4	2.29	0.05	10.00
Tilia cordata	10.2	1.27	0.03	10.00
Carya tomentosa	7.6	23.59	0.50	6.67
Ailanthus altissima	6.9	1.50	0.03	6.67
Quercus montana	6.9	0.10	0.002	6.67
Gleditsia triacanthos	4.2	29.37	0.62	3.33
Ulmus glabra	4.0	2.69	0.06	3.33
Carya glabra	3.7	8.76	0.19	3.33

Pinus strobus	3.7	0.40	0.01	3.33
Ostrya virginiana	3.6	1.71	0.04	3.33
Nyssa sylvatica	3.5	0.09	0.002	3.33
Populus deltoides	3.5	0.80	0.02	3.33
Quercus bicolor	3.5	0.53	0.01	3.33
Juglans nigra	3.4	0.30	0.01	3.33
Platanus occidentalis	3.4	0.22	0.005	3.33
Ulmus parvifolia	3.4	0.06	0.001	3.33
Betula nigra	3.4	0.02	0.001	3.33
Broussonetia papyrifera	3.4	0.02	0.0004	3.33
Tilia americana	3.4	0.02	0.0004	3.33
Acer platanoides	3.4	61.37	1.31	0.23
Betula populifolia	3.3	0.19	0.004	3.33
Acer pseudoplatanus	2.4	31.09	0.66	0.17
Acer negundo	1.6	3.83	0.08	0.10
Carya ovata		0.00		
Morus rubra		0.00		
Quercus velutina		0.00		
Ulmus americana		0.00		
Cornus florida		0.00		
Unrestored				
Sassafras albidum	118.9	1589.70	47.61	40.00
Prunus serotina	103.1	429.96	12.88	73.33
Robinia pseudoacacia	66.2	720.21	21.57	33.33
Carya cordiformis	37.4	45.80	1.37	30.00
Liquidambar styraciflua	31.8	185.95	5.57	23.33
Morus alba	29.5	59.51	1.78	23.33
Acer rubrum	23.9	33.24	1.00	20.00
Quercus palustris	22.3	34.85	1.04	20.00
Carya ovata	20.1	37.09	1.11	16.67
Fraxinus pennsylvanica	19.9	45.53	1.36	16.67
Quercus rubra	18.8	29.75	0.89	16.67
Liriodendron tulipifera	18.7	19.92	0.60	16.67
Juglans nigra	18.2	16.20	0.49	16.67
Fraxinus americana	16.5	1.95	0.06	13.33
Quercus velutina	14.6	7.52	0.23	13.33
Acer saccharum	11.5	23.27	0.70	6.67
Ailanthus altissima	11.1	1.59	0.05	10.00
Quercus alba	11.1	8.13	0.24	10.00
Ulmus americana	7.7	20.07	0.60	6.67
Ulmus rubra	7.0	9.94	0.30	6.67
Populus deltoides	3.9	11.79	0.35	3.33
Tilia americana	3.8	0.79	0.02	3.33

Cornus florida	3.6	0.50	0.02	3.33
Morus rubra	3.5	0.10	0.003	3.33
Acer platanoides	3.4	5.17	0.15	0.30
Acer pseudoplatanus	0.5	0.24	0.01	0.07
Acer negundo		0.00		
Acer saccharinum		0.00		
Aesculus hippocastanum		0.00		
Betula lenta		0.00		
Betula nigra		0.00		
Betula populifolia		0.00		
Broussonetia papyrifera		0.00		
Carya glabra		0.00		
Carya tomentosa		0.00		
Celtis occidentalis		0.00		
Fagus grandifolia		0.00		
Gleditsia triacanthos		0.00		
Nyssa sylvatica		0.00		
Ostrya virginiana		0.00		
Pinus strobus		0.00		
Platanus occidentalis		0.00		
Prunus avium		0.00		
Quercus bicolor		0.00		
Quercus montana		0.00		
Tilia cordata		0.00		
Ulmus glabra		0.00		
Ulmus parvifolia		0.00		

A.3.1.1 Shade Tolerance of Trees

A.2. Shade tolerant trees in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of shade tolerant trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Shade Tolerant Cover	% Total Basal Area	% of Plots
Restored					
Fraxinus pennsylvanica	66.70	172.56	53.1	3.7	53.3
Acer saccharum	56.75	84.44	26.0	1.8	50.0
Celtis occidentalis	38.54	46.44	7.2	1.0	33.3
Ulmus rubra	34.65	61.66	19.0	1.3	33.3
Fagus grandifolia	10.75	0.47	0.1	0.01	10.0
Ostrya virginiana	3.58	1.71	0.5	0.04	3.3
Nyssa sylvatica	3.55	0.09	0.03	0.002	3.3
Tilia americana	3.44	0.02			
Acer negundo	1.55	3.83	1.2	0.1	10.0
Cornus florida		0.00			
Morus rubra		0.00			
Unrestored					
Fraxinus pennsylvanica	19.91	45.53	52	1.4	16.7
Acer saccharum	11.54	23.27	26.5	0.7	6.7
Ulmus rubra	6.96	9.94	11.3	0.3	6.7
Tilia americana	3.77	0.79	0.9	0.02	6.7
Cornus florida	3.56	0.50	0.6	0.02	3.3
Morus rubra	3.54	0.10	0.1	0.003	3.3
Acer negundo		0.00			
Celtis occidentalis		0.00			
Fagus grandifolia		0.00			
Nyssa sylvatica		0.00			
Ostrya virginiana		0.00			

A.3. Trees with intermediate shade tolerance in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of intermediate shade tolerant trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Intermediate Shade Tolerant Basal Area	% Total Basal Area	% of Plots
Restored					
Quercus rubra	56.47	306.99	47.5	6.5	46.7
Acer rubrum	41.93	189.12	29.3	4.0	30.0
Morus alba	25.42	18.74	2.9	0.4	23.3
Prunus avium	24.86	2.21	0.3	0.05	23.3
Quercus alba	10.70	12.91	2.0	0.3	10.0
Acer saccharinum	10.43	0.62	0.1	0.01	10.0
Aesculus hippocastanum	10.36	2.29	0.4	0.05	10.0
Tilia cordata	10.24	1.27	0.2	0.03	10.0
Quercus montana	6.88	0.10	0.02	0.002	6.7
Ulmus glabra	4.02	2.69	0.4	0.1	3.3
Carya glabra	3.73	8.76	0.23	0.19	3.30
Pinus strobus	3.66	0.40	0.1	0.01	3.3
Quercus bicolor	3.45	0.53	0.1	0.01	3.3
Platanus occidentalis	3.44	0.22	0.03	0.005	3.3
Acer platanoides	3.44	61.37	9.5	1.3	23.3
Betula populifolia	3.34	0.19	0.01	0.004	3.30
Carya ovata		0.00			
Quercus velutina		0.00			
Ulmus americana		0.00			
Unrestored					
Morus alba	29.50	59.51	30.8	1.8	23.3
Acer rubrum	23.92	33.24	17.2	1.0	20.0
Carya ovata	20.07	37.09	19.2	1.1	16.7
Quercus rubra	18.81	29.75	15.4	0.9	16.7
Quercus velutina	14.60	7.52	8.6	0.2	13.3
Quercus alba	11.08	8.13	4.2	0.2	10.0
Ulmus americana	7.69	20.07	10.4	0.6	6.7
Acer platanoides	3.38	5.17	2.7	0.2	30.0
Acer saccharinum		0.00			
Aesculus hippocastanum		0.00			

Betula populifolia	0.00
Carya glabra	0.00
Pinus strobus	0.00
Platanus occidentalis	0.00
Prunus avium	0.00
Quercus bicolor	0.00
Quercus montana	0.00
Tilia cordata	0.00
Ulmus glabra	0.00

A.4. Trees with shade intolerance in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of shade intolerant trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Shade Intolerant Basal Area	% Total Basal Area	% of Plots
Restored					
Prunus serotina	102.53	492.37	13.20	10.48	76.70
Robinia pseudoacacia	85.90	1741.19	46.70	37.05	40.00
Liriodendron tulipifera	73.25	468.81	12.57	9.98	50.00
Carya cordiformis	58.85	593.89	15.93	12.64	40.00
Quercus palustris	28.61	173.72	4.66	3.70	23.30
Liquidambar styraciflua	22.99	76.24	2.04	1.62	20.00
Sassafras albidum	20.85	43.23	1.16	0.92	16.70
Betula lenta	18.67	10.03	0.27	0.21	16.70
Fraxinus americana	15.25	33.68	0.90	0.72	10.00
Carya tomentosa	7.59	23.59	0.63	0.50	6.70
Ailanthus altissima	6.91	1.50	0.04	0.03	6.70
Gleditsia triacanthos	4.17	29.37	0.79	0.62	3.30
Populus deltoides	3.46	0.80	0.02	0.02	3.30
Juglans nigra	3.45	0.30	0.01	0.01	3.30
Ulmus parvifolia	3.44	0.06	0.002	0.001	3.30
Betula nigra	3.44	0.02	0.001	0.001	3.30
Acer pseudoplatanus	2.41	31.09	0.83	0.66	16.70
Unrestored					
Sassafras albidum	118.93	1589.70	51.98	47.61	40.0
Prunus serotina	103.12	429.96	14.06	12.88	73.3
Robinia pseudoacacia	66.18	720.21	23.55	21.57	33.3
Carya cordiformis	37.43	45.80	1.50	1.37	30.0

Liquidambar styraciflua	31.83	185.95	6.08	5.57	23.3
Quercus palustris	22.30	34.85	1.14	1.04	20.0
Liriodendron tulipifera	18.72	19.92	0.65	0.60	16.7
Juglans nigra	18.20	16.20	0.53	0.49	16.7
Fraxinus americana	16.52	1.95	0.06	0.06	13.3
Ailanthus altissima	11.09	1.59	0.05	0.05	10.0
Populus deltoides	3.90	11.79	0.39	0.35	3.3
Broussonetia papyrifera	3.44	0.02	0.003	0.0004	3.3
Acer pseudoplatanus	0.49	0.24	0.01	0.01	6.7
Betula lenta		0.00			
Betula nigra		0.00			
Broussonetia papyrifera		0.00			
Carya tomentosa		0.00			
Gleditsia triacanthos		0.00			
Ulmus parvifolia		0.00			

A.3.1.2 Seed Dispersal of Trees

A.5. Trees with unassisted seed dispersal in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of trees with unassisted seed dispersal, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Unassisted Dispersal Basal Area	% Total Basal Area	% of Plots
Restored					
Robinia pseudoacacia	85.90	1741.19	98.12	37.05	40.00
Fagus grandifolia	10.75	0.47	0.03	0.01	10.00
Aesculus hippocastanum	10.36	2.29	0.13	0.05	10.00
Tilia cordata	10.24	1.27	0.07	0.03	10.00
Gleditsia triacanthos	4.17	29.37	1.65	0.62	3.33
Tilia americana	3.44	0.02	0.001	0.0004	3.33
Unrestored					
Robinia pseudoacacia	66.18	720.21	99.89	21.57	33.33
Tilia americana	3.77	0.79	0.11	0.02	3.33
Aesculus hippocastanum		0.00			
Fagus grandifolia		0.00			
Gleditsia triacanthos		0.00			
Tilia cordata		0.00			

A.6. Wind dispersed trees in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of wind dispersed trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	**IVI**	**Basal Area (m^2/ha)**	**% Wind Dispersal Basal Area**	**% Total Basal Area**	**% of Plots**
Restored					
Liriodendron tulipifera	73.25	468.81	39.09	9.98	50.00
Fraxinus pennsylvanica	66.70	172.56	14.39	3.67	53.33
Acer saccharum	56.75	84.44	7.04	1.80	50.00
Acer rubrum	41.93	189.12	15.77	4.02	30.00
Ulmus rubra	34.65	61.66	5.14	1.31	33.33
Liquidambar styraciflua	22.99	76.24	6.36	1.62	20.00
Betula lenta	18.67	10.03	0.84	0.21	16.67
Fraxinus americana	15.25	33.68	2.81	0.72	10.00
Acer saccharinum	10.43	0.62	0.05	0.01	10.00
Ailanthus altissima	6.91	1.50	0.13	0.03	6.67
Ulmus glabra	4.02	2.69	0.22	0.06	3.33
Pinus strobus	3.66	0.40	0.03	0.01	3.33
Populus deltoides	3.46	0.80	0.07	0.02	3.33
Platanus occidentalis	3.44	0.22	0.02	0.005	3.33
Ulmus parvifolia	3.44	0.06	0.005	0.001	3.33
Betula nigra	3.44	0.02	0.002	0.001	3.33
Acer platanoides	3.44	61.37	5.12	1.31	0.23
Betula populifolia	3.34	0.19	0.02	0.004	3.33
Acer pseudoplatanus	2.41	31.09	2.59	0.66	0.17
Acer negundo	1.55	3.83	0.32	0.08	0.10
Ulmus americana		0.00			
Unrestored					
Liquidambar styraciflua	31.83	185.95	51.85	5.57	23.33
Acer rubrum	23.92	33.24	9.27	1.00	20.00
Fraxinus pennsylvanica	19.91	45.53	12.69	1.36	16.67
Liriodendron tulipifera	18.72	19.92	5.55	0.60	16.67
Fraxinus americana	16.52	1.95	0.54	0.06	13.33
Acer saccharum	11.54	23.27	6.49	0.70	6.67

Ailanthus altissima	11.09	1.59	0.44	0.05	10.00
Ulmus americana	7.69	20.07	5.60	0.60	6.67
Ulmus rubra	6.96	9.94	2.77	0.30	6.67
Populus deltoides	3.90	11.79	3.29	0.35	3.33
Acer platanoides	3.38	5.17	1.44	0.15	0.30
Acer pseudoplatanus	0.49	0.24	0.07	0.01	0.07
Acer negundo		0.00			
Acer saccharinum		0.00			
Betula lenta		0.00			
Betula nigra		0.00			
Betula populifolia		0.00			
Pinus strobus		0.00			
Platanus occidentalis		0.00			
Ulmus glabra		0.00			
Ulmus parvifolia		0.00			

A.7. Endozoochoric trees in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of endozoochoric trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Endozoochory Basal Area	% Total Basal Area	% of Plots
Restored					
Prunus serotina	102.53	492.37	81.64	10.48	76.67
Celtis occidentalis	38.54	46.44	7.70	0.99	33.33
Morus alba	25.42	18.74	3.11	0.40	23.33
Prunus avium	24.86	2.21	0.37	0.05	23.33
Sassafras albidum	20.85	43.23	7.17	0.92	16.67
Nyssa sylvatica	3.55	0.09	0.02	0.002	3.33
Broussonetia papyrifera	3.44	0.02	0.003	0.0004	3.33
Cornus florida		0.00			
Morus rubra		0.00			
Unrestored					
Sassafras albidum	118.93	1589.70	76.44	47.61	40.00
Prunus serotina	103.12	429.96	20.67	12.88	73.33
Morus alba	29.50	59.51	2.86	1.78	23.33
Cornus florida	3.56	0.50	0.02	0.02	3.33
Morus rubra	3.54	0.10	0.005	0.003	3.33
Broussonetia papyrifera		0.00			
Celtis occidentalis		0.00			
Nyssa sylvatica		0.00			
Prunus avium		0.00			

A.8. Seed hoarded trees in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of basal area of seed hoarded trees, percent of total basal area, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI. Native species are bolded.

Species	IVI	Basal Area (m^2/ha)	% Hoarding Basal Area	% Total Basal Area	% of Plots
Restored					
Carya cordiformis	58.85	593.89	52.99	12.64	40.00
Quercus rubra	56.47	306.99	27.39	6.53	46.67
Quercus palustris	28.61	173.72	15.50	3.70	23.33
Quercus alba	10.70	12.91	1.15	0.27	10.00
Carya tomentosa	7.59	23.59	2.10	0.50	6.67
Quercus montana	6.88	0.10	0.01	0.00	6.67
Carya glabra	3.73	8.76	0.78	0.19	3.33
Quercus bicolor	3.45	0.53	0.05	0.01	3.33
Juglans nigra	3.45	0.30	0.03	0.01	3.33
Carya ovata		0.00			
Quercus velutina		0.00			
Unrestored					
Carya cordiformis	37.43	45.80	57.73	1.37	30.00
Quercus palustris	22.30	34.85	43.93	1.04	20.00
Carya ovata	20.07	37.09	46.74	1.11	16.67
Quercus rubra	18.81	29.75	37.50	0.89	16.67
Juglans nigra	18.20	16.20	20.42	0.49	16.67
Quercus velutina	14.60	7.52	9.48	0.23	13.33
Quercus alba	11.08	8.13	10.24	0.24	10.00
Carya glabra		0.00			
Carya tomentosa		0.00			
Quercus bicolor		0.00			
Quercus montana		0.00			

A.3.1.3 Pollination of Trees

A.9. Abiotically pollinated tree species in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area of abiotically pollinated trees, percent of total basal area in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Basal Area (m^2/ha)**	**% Abiotic Pollination Basal Area**	**% Total Basal Area**	**% of Plots**
Fraxinus pennsylvanica	66.7	172.56	11.73	3.67	53.3
Carya cordiformis	58.9	593.89	40.39	12.64	40.0
Quercus rubra	56.5	306.99	20.88	6.53	46.7
Celtis occidentalis	38.5	46.44	3.16	0.99	33.3
Ulmus rubra	34.6	61.66	4.19	1.31	33.3
Quercus palustris	28.6	173.72	11.81	3.70	23.3
Morus alba	25.4	18.74	1.27	0.40	23.3
Betula lenta	18.7	10.03	0.68	0.21	16.7
Fraxinus americana	15.2	33.68	2.29	0.72	10.0
Fagus grandifolia	10.7	0.47	0.03	0.01	10.0
Quercus alba	10.7	12.91	0.88	0.27	10.0
Carya tomentosa	7.6	23.59	1.60	0.50	6.7
Quercus montana	6.9	0.10	0.01	0.002	6.7
Ulmus glabra	4.0	2.69	0.18	0.06	3.3
Carya glabra	3.7	8.76	0.60	0.19	3.3
Pinus strobus	3.7	0.40	0.03	0.01	3.3
Ostrya virginiana	3.6	1.71	0.12	0.04	3.3
Populus deltoides	3.5	0.80	0.05	0.02	3.3
Quercus bicolor	3.5	0.53	0.04	0.01	3.3
Juglans nigra	3.4	0.30	0.02	0.01	3.3
Platanus occidentalis	3.4	0.22	0.01	0.005	3.3
Ulmus parvifolia	3.4	0.06	0.004	0.001	3.3
Betula nigra	3.4	0.02	0.002	0.001	3.3
Broussonetia papyrifera	3.4	0.02	0.001	0.0004	3.3
Betula populifolia	3.3	0.19	0.01	0.004	3.3
Carya ovata		0.00			
Morus rubra		0.00			

Quercus velutina		0.00			
Ulmus americana		0.00			
Unrestored					
Carya cordiformis	37.4	45.80	13.96	1.37	30.0
Morus alba	29.5	59.51	18.13	1.78	23.3
Quercus palustris	22.3	34.85	10.62	1.04	20.0
Carya ovata	20.1	37.09	11.30	1.11	16.7
Fraxinus pennsylvanica	19.9	45.53	13.87	1.36	16.7
Quercus rubra	18.8	29.75	9.06	0.89	16.7
Juglans nigra	18.2	16.20	4.94	0.49	16.7
Fraxinus americana	16.5	1.95	0.60	0.06	13.3
Quercus velutina	14.6	7.52	2.29	0.23	13.3
Quercus alba	11.1	8.13	2.48	0.24	10.0
Ulmus americana	7.7	20.07	6.11	0.60	6.7
Ulmus rubra	7.0	9.94	3.03	0.30	6.7
Populus deltoides	3.9	11.79	3.59	0.35	3.3
Morus rubra	3.5	0.10	0.03	0.003	3.3
Betula lenta		0.00			
Betula nigra		0.00			
Betula populifolia		0.00			
Broussonetia papyrifera		0.00			
Carya glabra		0.00			
Carya tomentosa		0.00			
Celtis occidentalis		0.00			
Fagus grandifolia		0.00			
Ostrya virginiana		0.00			
Pinus strobus		0.00			
Platanus occidentalis		0.00			
Quercus bicolor		0.00			
Quercus montana		0.00			
Ulmus glabra		0.00			
Ulmus parvifolia		0.00			

A.10. Biotically pollinated tree species in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area of biotically pollinated trees, percent of total basal area in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	Basal Area (m^2/ha)	IVI	% Biotic Pollination Basal Area	% Total Basal Area	% of Plots
Restored					
Prunus serotina	492.37	102.53	15.25	10.48	76.67
Robinia pseudoacacia	1741.19	85.90	53.92	37.05	40.00
Liriodendron tulipifera	468.81	73.25	14.52	9.98	50.00
Acer saccharum	84.44	56.75	2.62	1.80	50.00
Acer rubrum	189.12	41.93	5.86	4.02	30.00
Prunus avium	2.21	24.86	0.07	0.05	23.33
Liquidambar styraciflua	76.24	22.99	2.36	1.62	20.00
Sassafras albidum	43.23	20.85	1.34	0.92	16.67
Acer saccharinum	0.62	10.43	0.02	0.01	10.00
Aesculus hippocastanum	2.29	10.36	0.07	0.05	10.00
Tilia cordata	1.27	10.24	0.04	0.03	10.00
Ailanthus altissima	1.50	6.91	0.05	0.03	6.67
Gleditsia triacanthos	29.37	4.17	0.91	0.62	3.33
Tilia americana	0.02	3.44	0.001	0.0004	3.33
Acer platanoides	61.37	3.44	1.90	1.31	0.23
Acer pseudoplatanus	31.09	2.41	0.96	0.66	0.17
Acer negundo	3.83	1.55	0.12	0.08	0.10
Cornus florida	0.00				
Unrestored					
Sassafras albidum	1589.70	118.93	52.80	47.61	40.00
Prunus serotina	429.96	103.12	14.28	12.88	73.33
Robinia pseudoacacia	720.21	66.18	23.92	21.57	33.33
Liquidambar styraciflua	185.95	31.83	6.18	5.57	23.33
Acer rubrum	33.24	23.92	1.10	1.00	20.00
Liriodendron tulipifera	19.92	18.72	0.66	0.60	16.67
Acer saccharum	23.27	11.54	0.77	0.70	6.67

Ailanthus altissima	1.59	11.09	0.05	0.05	10.00
Tilia americana	0.79	3.77	0.03	0.02	3.33
Cornus florida	0.50	3.56	0.02	0.02	3.33
Acer platanoides	5.17	3.38	0.17	0.15	0.30
Acer pseudoplatanus	0.24	0.49	0.01	0.01	0.07
Aesculus hippocastanum	0.00	0.00			
Acer negundo	0.00				
Acer saccharinum	0.00				
Gleditsia triacanthos	0.00				
Prunus avium	0.00				
Tilia cordata	0.00				

A.3.1.4 Lifespan of Trees

A.11. Tree species with long lifespans in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area of trees with long lifespan, percent of total basal area in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Basal Area (m^2/ha)	% Long Lifespan Basal Area	% Total Basal Area	% of Plots
Restored					
Acer saccharum	56.75	84.44	17.38	1.80	50.00
Quercus rubra	56.47	306.99	63.20	6.53	46.67
Liquidambar styraciflua	22.99	76.24	15.69	1.62	20.00
Fagus grandifolia	10.75	0.47	0.10	0.01	10.00
Quercus alba	10.70	12.91	2.66	0.27	10.00
Tilia cordata	10.24	1.27	0.26	0.03	10.00
Ulmus glabra	4.02	2.69	0.55	0.06	3.33
Quercus bicolor	3.45	0.53	0.11	0.01	3.33
Platanus occidentalis	3.44	0.22	0.04	0.00	3.33
Ulmus americana		0.00			
Unrestored					
Liquidambar styraciflua	31.83	185.95	69.60	5.57	23.33
Quercus rubra	18.81	29.75	11.14	0.89	16.67
Acer saccharum	11.54	23.27	8.71	0.70	6.67
Quercus alba	11.08	8.13	3.04	0.24	10.00
Ulmus americana	7.69	20.07	7.51	0.60	6.67
Fagus grandifolia		0.00			
Platanus occidentalis		0.00			
Quercus bicolor		0.00			
Tilia cordata		0.00			
Ulmus glabra		0.00			

A.12. Tree species with moderate lifespan in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area of trees with moderate lifespan, percent of total basal area in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Basal Area (m^2/ha)	% Moderate Lifespan Basal Area	% Total Basal Area	% of Plots
Restored					
Prunus serotina	102.53	492.37	25.00	10.48	76.67
Liriodendron tulipifera	73.25	468.81	23.80	9.98	50.00
Carya cordiformis	58.85	593.89	30.15	12.64	40.00
Celtis occidentalis	38.54	46.44	2.36	0.99	33.33
Ulmus rubra	34.65	61.66	3.13	1.31	33.33
Quercus palustris	28.61	173.72	8.82	3.70	23.33
Morus alba	25.42	18.74	0.95	0.40	23.33
Betula lenta	18.67	10.03	0.51	0.21	16.67
Fraxinus americana	15.25	33.68	1.71	0.72	10.00
Gleditsia triacanthos	4.17	29.37	1.49	0.62	3.33
Carya glabra	3.73	8.76	0.44	0.19	3.33
Pinus strobus	3.66	0.40	0.02	0.01	3.33
Nyssa sylvatica	3.55	0.09	0.00	0.00	3.33
Juglans nigra	3.45	0.30	0.02	0.01	3.33
Ulmus parvifolia	3.44	0.06	0.00	0.00	3.33
Betula nigra	3.44	0.02	0.00	0.00	3.33
Tilia americana	3.44	0.02	0.00	0.00	3.33
Acer pseudoplatanus	2.41	31.09	1.58	0.66	0.17
Quercus velutina		0.00			
Unrestored					
Prunus serotina	103.12	429.96	68.61	12.88	73.33
Carya cordiformis	37.43	45.80	7.31	1.37	30.00
Morus alba	29.50	59.51	9.50	1.78	23.33
Quercus palustris	22.30	34.85	5.56	1.04	20.00

Liriodendron tulipifera	18.72	19.92	3.18	0.60	16.67
Juglans nigra	18.20	16.20	2.59	0.49	16.67
Fraxinus americana	16.52	1.95	0.31	0.06	13.33
Quercus velutina	14.60	7.52	1.20	0.23	13.33
Ulmus rubra	6.96	9.94	1.59	0.30	6.67
Tilia americana	3.77	0.79	0.13	0.02	3.33
Acer pseudoplatanus	0.49	0.24	0.04	0.01	0.07
Betula lenta		0.00			
Betula nigra		0.00			
Carya glabra		0.00			
Celtis occidentalis		0.00			
Gleditsia triacanthos		0.00			
Nyssa sylvatica		0.00			
Pinus strobus		0.00			
Ulmus parvifolia		0.00			

A.13. Tree species with short lifespan in restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Curtis and McIntosh 1951), total basal area, percent of total basal area of trees with short lifespan, percent of total basal area in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Basal Area (m^2/ha)**	**% Short Lifespan Basal Area**	**% Total Basal Area**	**% of Plots**
Restored					
Robinia pseudoacacia	85.90	1741.19	78.49	37.05	40.00
Fraxinus pennsylvanica	66.70	172.56	7.78	3.67	53.33
Acer rubrum	41.93	189.12	8.53	4.02	30.00
Prunus avium	24.86	2.21	0.10	0.05	23.33
Sassafras albidum	20.85	43.23	1.95	0.92	16.67
Acer saccharinum	10.43	0.62	0.03	0.01	10.00
Ailanthus altissima	6.91	1.50	0.07	0.03	6.67
Ostrya virginiana	3.58	1.71	0.08	0.04	3.33
Populus deltoides	3.46	0.80	0.04	0.02	3.33
Acer platanoides	3.44	61.37	2.77	1.31	0.23
Betula populifolia	3.34	0.19	0.01	0.00	3.33
Acer negundo	1.55	3.83	0.17	0.08	0.10
Cornus florida		0.00			
Unrestored					
Sassafras albidum	118.93	1589.70	66.02	47.61	40.00
Robinia pseudoacacia	66.18	720.21	29.91	21.57	33.33
Acer rubrum	23.92	33.24	1.38	1.00	20.00
Fraxinus pennsylvanica	19.91	45.53	1.89	1.36	16.67
Populus deltoides	11.79	11.79	0.49	0.35	3.33
Ailanthus altissima	11.09	1.59	0.07	0.05	10.00
Acer platanoides	5.17	5.17	0.21	0.15	0.30
Cornus florida	3.56	0.50	0.02	0.02	3.33
Acer negundo		0.00			
Acer saccharinum		0.00			
Betula populifolia		0.00			
Ostrya virginiana		0.00			
Prunus avium		0.00			

A.3.2 Woody Understory Species

A.3.2.1 Growth Form of Species in the Woody Understory

A.14. Species of tree saplings in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total tree sapling stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored **Species**	**IVI**	**Stem Count**	**% Tree Stems**	**% Total Stems**	**% of Plots**
Fraxinus americana	27.7	79	22.83	5.40	50.00
Prunus serotina	23.2	46	13.29	3.14	43.33
Carya cordiformis	19.9	46	13.29	3.14	36.67
Quercus rubra	12.1	13	3.76	0.89	23.33
Acer pseudoplatanus	10.7	20	5.78	1.37	20.00
Acer platanoides	10.3	10	2.89	0.68	20.00
Acer negundo	9.5	34	9.83	2.32	16.67
Acer saccharum	8.9	17	4.91	1.16	16.67
Liriodendron tulipifera	8.5	6	1.73	0.41	16.67
Acer rubrum	6.9	7	2.02	0.48	13.33
Morus alba	6.9	6	1.73	0.41	13.33
Sassafras albidum	5.3	10	2.89	0.68	10.00
Quercus alba	5.2	5	1.45	0.34	10.00
Quercus montana	5.2	5	1.45	0.34	10.00
Prunus avium	5.1	4	1.16	0.27	10.00
Fraxinus pennsylvanica	3.7	10	2.89	0.68	6.67
Ulmus pumila	3.6	8	2.31	0.55	6.67
Celtis occidentalis	3.6	7	2.02	0.48	6.67
Ostrya virginiana	1.8	3	0.87	0.20	3.33
Nyssa sylvatica	1.7	2	0.58	0.14	3.33
Populus alba	1.7	2	0.58	0.14	3.33
Zanthoxylum simulans	1.7	2	0.58	0.14	3.33
Acer saccharinum	1.7	1	0.29	0.07	3.33
Broussonetia papyrifera	1.7	1	0.29	0.07	3.33
Pinus strobus	1.7	1	0.29	0.07	3.33

Quercus velutina	1.7	1	0.29	0.07	3.33
Ailanthus altissima		0			
Ilex crenata		0			
Juglans nigra		0			
Robinia pseudoacacia		0			
Unrestored					
Sassafras albidum	19.0	44	30.34	1.32	36.67
Celtis occidentalis	5.6	40	27.59	1.20	10.00
Prunus serotina	3.7	25	17.24	0.75	6.67
Carya cordiformis	8.5	9	6.21	0.27	16.67
Ailanthus altissima	6.8	7	4.83	0.21	13.33
Acer platanoides	1.7	5	3.45	0.15	3.33
Acer saccharum	1.7	4	2.76	0.12	3.33
Acer rubrum	3.4	2	1.38	0.06	6.67
Fraxinus americana	1.7	2	1.38	0.06	3.33
Fraxinus pennsylvanica	1.7	2	1.38	0.06	3.33
Ilex crenata	1.7	2	1.38	0.06	3.33
Juglans nigra	1.7	1	0.69	0.03	3.33
Quercus velutina	1.7	1	0.69	0.03	3.33
Robinia pseudoacacia	1.7	1	0.69	0.03	3.33
Acer negundo		0			
Acer pseudoplatanus		0			
Acer saccharinum		0			
Broussonetia papyrifera		0			
Liriodendron tulipifera		0			
Morus alba		0			
Nyssa sylvatica		0			
Ostrya virginiana		0			
Pinus strobus		0			
Populus alba		0			
Prunus avium		0			
Quercus alba		0			
Quercus montana		0			
Quercus rubra		0			
Ulmus pumila		0			
Zanthoxylum simulans		0			

A.15. Species of shrubs in the woody understory of restored plots (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total shrub stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored **Species**	**IVI**	**Stem Count**	**% Shrub Stems**	**% Total Stems**	**% of Plots**
Lindera benzoin	28.33	244	34.37	16.67	40.00
Rosa multiflora	22.03	157	22.11	10.72	33.33
Lonicera maackii	16.50	44	6.20	3.01	30.00
Rubus phoenicolasius	12.73	31	4.37	2.12	23.33
Viburnum dentatum	11.54	94	13.24	6.42	16.67
Rubus pensilvanicus	9.90	46	6.48	3.14	16.67
Ligustrum obtusifolium	5.85	25	3.52	1.71	10.00
Aronia arbutifolia	5.38	11	1.55	0.75	10.00
Rubus occidentalis	5.27	8	1.13	0.55	10.00
Rhodotypos scandens	3.64	9	1.27	0.61	6.67
Rhamnus cathartica	3.40	2	0.28	0.14	6.67
Frangula alnus	1.94	8	1.13	0.55	3.33
Cornus racemosa	1.91	7	0.99	0.48	3.33
Forsythia xintermedia	1.87	6	0.85	0.41	3.33
Corylus americana	1.84	5	0.70	0.34	3.33
Sambucus nigra	1.77	3	0.42	0.20	3.33
Philadelphus lewisii	1.73	2	0.28	0.14	3.33
Rubus odoratus	1.73	2	0.28	0.14	3.33
Amelanchier arborea	1.70	1	0.14	0.07	3.33
Clethra alnifolia	1.70	1	0.14	0.07	3.33
Ilex opaca	1.70	1	0.14	0.07	3.33
Rhus typhina	1.70	1	0.14	0.07	3.33
Rubus allegheniensis	1.70	1	0.14	0.07	3.33
Viburnum prunifolium	1.70	1	0.14	0.07	3.33
Euonymus alatus		0			
Lonicera morrowii		0			
Philadelphus coronarius		0			

Philadelphus tomentosus		0			
Rhus glabra		0			
Taxus baccata		0			
Viburnum dilatatum		0			
Viburnum plicatum		0			
Viburnum sieboldii		0			
Unrestored					
Rosa multiflora	63.37	999	60.73	30.08	96.67
Rubus pensilvanicus	32.93	305	18.54	9.18	56.67
Viburnum dentatum	18.26	106	6.44	3.19	33.33
Rubus phoenicolasius	10.96	64	3.89	1.93	20.00
Rubus occidentalis	10.53	35	2.13	1.05	20.00
Lindera benzoin	10.17	11	0.67	0.33	20.00
Lonicera maackii	5.47	31	1.88	0.93	10.00
Rubus allegheniensis	5.42	28	1.70	0.84	10.00
Lonicera morrowii	5.15	10	0.61	0.30	10.00
Philadelphus coronarius	3.54	14	0.85	0.42	6.67
Sambucus nigra	3.47	9	0.55	0.27	6.67
Ligustrum obtusifolium	3.44	7	0.43	0.21	6.67
Viburnum prunifolium	3.39	4	0.24	0.12	6.67
Rhus glabra	1.76	6	0.36	0.18	3.33
Rhodotypos scandens	1.74	5	0.30	0.15	3.33
Viburnum dilatatum	1.74	5	0.30	0.15	3.33
Philadelphus tomentosus	1.71	3	0.18	0.09	3.33
Viburnum plicatum	1.70	2	0.12	0.06	3.33
Euonymus alatus	1.68	1	0.06	0.03	3.33
Taxus baccata	1.68	1	0.06	0.03	3.33
Viburnum sieboldii	1.68	1	0.06	0.03	3.33
Amelanchier arborea		0			
Aronia arbutifolia		0			
Clethra alnifolia		0			
Cornus racemosa		0			
Corylus americana		0			
Forsythia xintermedia		0			
Frangula alnus		0			
Ilex opaca		0			
Philadelphus lewisii		0			
Rhamnus cathartica		0			
Rhus typhina		0			
Rubus odoratus		0			

A.16. Vine species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total vine stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Stem Count**	**% Vine Stems**	**% Total Stems**	**% of Plots**
Restored					
Ampelopsis brevipedunculata	19.7	39	9.56	2.66	36.67
Toxicodendron radicans	19.5	229	56.13	15.64	23.33
Lonicera japonica	18.6	57	13.97	3.89	33.33
Parthenocissus quinquefolia	13.8	13	3.19	0.89	26.67
Vitis riparia	8.0	40	9.80	2.73	13.33
Celastrus orbiculatus	5.9	25	6.13	1.71	10.00
Hedera helix	1.8	5	1.23	0.34	3.33
Humulus lupulus	0.0	0			0.00
Vitis aestivalis	0.0	0			0.00
Vitis labrusca	0.0	0			0.00
Vitis x novae-angliae	0.0	0			0.00
Wisteria sinensis	0.0	0			0.00
Unrestored					
Ampelopsis brevipedunculata	37.2	559	37.64	1.13	73.33
Lonicera japonica	37.0	308	20.74	0.62	73.33
Celastrus orbiculatus	35.3	268	18.05	0.54	70.00
Toxicodendron radicans	21.7	46	3.10	0.09	43.33
Parthenocissus quinquefolia	20.1	73	4.92	0.15	40.00
Vitis aestivalis	16.8	94	6.33	0.19	33.33
Vitis labrusca	6.7	80	5.39	0.16	13.33
Vitis riparia	3.4	39	2.63	0.08	6.67
Wisteria sinensis	1.7	10	0.67	0.02	3.33
Humulus lupulus	1.7	7	0.47	0.01	3.33
Vitis x novae-angliae	1.7	1	0.07	0.00	3.33
Hedera helix	0.0	0			0.00

A.3.2.2 Shade Tolerance of Species in the Woody Understory

A.17. Shade tolerant species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total shade tolerant stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Shade Tolerant Stems	%Total Stems	% of Plots
Restored					
Lonicera japonica	18.6	57	18.15	3.49	33.33
Rubus pensilvanicus	9.9	46	14.65	3.14	16.67
Acer negundo	9.5	34	10.83	2.32	16.67
Acer saccharum	8.9	17	5.41	1.16	16.67
Celastrus orbiculatus	5.9	25	7.96	1.71	10.00
Fraxinus pennsylvanica	3.7	10	3.18	0.68	6.67
Celtis occidentalis	3.6	7	0.99	0.48	6.67
Rhodotypos scandens	3.6	9	2.87	0.61	6.67
Cornus racemosa	1.9	7	2.23	0.48	3.33
Hedera helix	1.8	5	1.59	0.34	3.33
Ostrya virginiana	1.8	3	0.96	0.20	3.33
Nyssa sylvatica	1.7	2	0.64	0.14	3.33
Amelanchier arborea	1.7	1	0.32	0.07	3.33
Broussonetia papyrifera	1.7	1	0.14	0.07	3.33
Ilex opaca	1.7	1	0.32	0.07	3.33
Rubus allegheniensis	1.7	1	0.32	0.07	3.33
Viburnum prunifolium	1.7	1	0.32	0.07	3.33
Euonymus alatus		0			
Ilex crenata		0			
Lonicera morrowii		0			
Taxus baccata		0			
Vitis aestivalis		0			
Unrestored					
Lonicera japonica	41.3	308	27.09	9.27	73.33

Celastrus orbiculatus	39.0	268	23.57	8.07	70.00
Rubus pensilvanicus	32.9	305	26.82	9.18	56.67
Vitis aestivalis	18.1	94	8.27	2.83	33.33
Celtis occidentalis	5.6	40	4.42	1.20	10.00
Rubus allegheniensis	5.4	28	2.46	0.84	10.00
Lonicera morrowii	5.2	10	0.88	0.30	10.00
Viburnum prunifolium	3.4	4	0.35	0.12	6.67
Acer saccharum	1.7	4	0.35	0.12	3.33
Rhodotypos scandens	1.7	3	0.26	0.09	3.33
Fraxinus pennsylvanica	1.7	2	0.18	0.06	3.33
Ilex crenata	1.7	2	0.18	0.06	3.33
Euonymus alatus	1.7	1	0.09	0.03	3.33
Taxus baccata	1.7	1	0.09	0.03	3.33
Acer negundo		0			
Amelanchier arborea		0			
Broussonetia papyrifera		0			
Cornus racemosa		0			
Hedera helix		0			
Ilex opaca		0			
Nyssa sylvatica		0			
Ostrya virginiana		0			

A.18. Species with intermediate shade tolerance in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total intermediate shade tolerant stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Stem Count**	**% Shade Intolerant Stems**	**%Total Stems**	**% of Plots**
Lindera benzoin	28.3	244	34.56	16.67	40.00
Ampelopsis brevipedunculata	19.7	39	5.52	2.66	36.67
Toxicodendron radicans	19.5	229	32.44	15.64	23.33
Lonicera maackii	16.5	44	9.95	3.01	30.00
Parthenocissus quinquefolia	13.8	13	1.84	0.89	26.67
Rubus phoenicolasius	12.7	31	4.39	2.12	23.33
Quercus rubra	12.1	13	1.84	0.89	23.33
Viburnum dentatum	11.5	94	29.94	6.42	16.67
Acer platanoides	10.3	10	1.42	0.68	20.00
Vitis riparia	8.0	40	5.67	2.73	13.33
Acer rubrum	6.9	7	0.99	0.48	13.33
Morus alba	6.9	6	0.85	0.41	13.33
Ligustrum obtusifolium	5.9	25	3.54	1.71	10.00
Rubus occidentalis	5.3	8	1.13	0.55	10.00
Quercus alba	5.2	5	0.71	0.34	10.00
Quercus montana	5.2	5	0.71	0.34	10.00
Prunus avium	5.1	4	0.57	0.27	10.00
Rhamnus cathartica	3.4	2	0.45	0.14	6.67
Forsythia x intermedia	1.9	6	0.85	0.41	3.33
Corylus americana	1.8	5	0.71	0.34	3.33
Rubus odoratus	1.7	2	0.28	0.14	3.33
Acer saccharinum	1.7	1	0.14	0.07	3.33
Clethra alnifolia	1.7	1	0.14	0.07	3.33
Quercus velutina	1.7	1	0.32	0.07	3.33
Pinus strobus	1.7	1	0.14	0.07	3.33
Humulus lupulus		0			
Viburnum dilatatum		0			
Viburnum plicatum		0			

Viburnum sieboldii		0			
Vitis labrusca	0.0	0			
Unrestored					
Ampelopsis brevipedunculata	45.1	559	61.77	16.83	73.33
Toxicodendron radicans	22.4	46	5.08	1.39	43.33
Parthenocissus quinquefolia	21.1	73	8.07	2.20	40.00
Viburnum dentatum	18.3	106	9.32	3.19	33.33
Rubus phoenicolasius	11.0	64	7.07	1.93	20.00
Rubus occidentalis	10.5	35	3.87	1.05	20.00
Lindera benzoin	10.2	11	1.22	0.33	20.00
Vitis labrusca	9.4	80	6.27	5.46	13.33
Lonicera maackii	6.1	31	2.43	2.12	10.00
Vitis riparia	3.9	39	4.31	1.17	6.67
Ligustrum obtusifolium	3.4	7	0.77	0.21	6.67
Acer rubrum	3.4	2	0.22	0.06	6.67
Wisteria sinensis	2.0	10	0.78	0.68	3.33
Humulus lupulus	1.8	7	0.77	0.21	3.33
Acer platanoides	1.7	5	0.55	0.15	3.33
Quercus velutina	1.7	1	0.09	0.03	3.33
Viburnum dilatatum	1.7	5	0.55	0.15	3.33
Viburnum plicatum	1.7	2	0.22	0.06	3.33
Viburnum sieboldii	1.7	1	0.11	0.03	3.33
Acer saccharinum		0			
Clethra alnifolia		0			
Corylus americana		0			
Forsythia xintermedia		0			
Morus alba		0			
Pinus strobus		0			
Prunus avium		0			
Quercus alba		0			
Quercus montana		0			
Quercus rubra		0			
Rhamnus cathartica		0			
Rubus odoratus		0			
Wisteria sinensis		0			

A.19. Shade intolerant species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total shade intolerant stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Shade Intolerant Stems	%Total Stems	% of Plots
Restored					
Fraxinus americana	27.7	79	17.87	5.40	50.00
Prunus serotina	23.2	46	10.41	3.14	43.33
Rosa multiflora	22.0	157	35.52	10.72	33.33
Carya cordiformis	19.9	46	10.41	3.14	36.67
Acer pseudoplatanus	10.7	20	4.52	1.37	20.00
Liriodendron tulipifera	8.5	6	1.36	0.41	16.67
Aronia arbutifolia	5.4	11	2.49	0.75	10.00
Sassafras albidum	5.3	10	2.26	0.68	10.00
Ulmus pumila	3.6	8	1.81	0.55	6.67
Frangula alnus	1.9	8	1.81	0.55	3.33
Sambucus nigra	1.8	3	0.42	0.20	3.33
Philadelphus lewisii	1.7	2	0.45	0.14	3.33
Populus alba	1.7	2	0.45	0.14	3.33
Rhus typhina	1.7	1	0.23	0.07	3.33
Ailanthus altissima	0.0	0			
Juglans nigra	0.0	0			
Philadelphus coronarius	0.0	0			
Rhus glabra	0.0	0			
Robinia pseudoacacia	0.0	0			
Smilax rotundifolia	0.0	0			
Unrestored					
Rosa multiflora	82.5	999	78.35	68.24	96.67
Sassafras albidum	19.8	44	3.45	3.01	36.67
Smilax rotundifolia	9.9	46	3.61	3.14	16.67
Carya cordiformis	8.6	9	0.71	0.61	16.67
Ailanthus altissima	6.9	7	0.55	0.48	13.33
Prunus serotina	4.2	25	1.96	1.71	6.67

Philadelphus coronarius	3.8	14	1.10	0.96	6.67
Sambucus nigra	3.5	9	0.99	0.27	6.67
Rhus glabra	1.9	6	0.47	0.41	3.33
Fraxinus americana	1.7	2	0.16	0.14	3.33
Juglans nigra	1.7	1	0.08	0.07	3.33
Robinia pseudoacacia	1.7	1	0.08	0.07	3.33
Acer pseudoplatanus		0			
Aronia arbutifolia		0			
Frangula alnus		0			
Liriodendron tulipifera		0			
Philadelphus lewisii		0			
Populus alba		0			
Rhus typhina		0			
Ulmus pumila		0			

A.3.2.3 Seed Dispersal of Species in the Woody Understory

A.20. Species with unassisted seed dispersal in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total stems with unassisted seed dispersal, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Unassisted Dispersal Stems	% Total Stems	% of Plots
Restored					
Ligustrum obtusifolium	5.9	25	96.15	1.71	10.00
Clethra alnifolia	1.7	1	3.85	0.07	3.33
Philadelphus coronarius		0			
Robinia pseudoacacia		0			
Unrestored					
Philadelphus coronarius	3.5	14	63.64	0.42	6.67
Ligustrum obtusifolium	3.4	7	31.82	0.21	6.67
Robinia pseudoacacia	1.7	1	4.55	0.03	3.33
Clethra alnifolia		0			

A. 21. Wind dispersed species in the woody understory of restored plots (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total stems with wind dispersal, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Wind Dispersed Stems	% Total Stems	% of Plots
Restored					
Fraxinus americana	27.7	79	40.51	5.40	50.00
Acer pseudoplatanus	10.7	20	10.26	1.37	20.00
Acer platanoides	10.3	10	5.13	0.68	20.00
Acer negundo	9.5	34	17.44	2.32	16.67
Acer saccharum	8.9	17	8.72	1.16	16.67
Liriodendron tulipifera	8.5	6	3.08	0.41	16.67
Acer rubrum	6.9	7	3.59	0.48	13.33
Fraxinus pennsylvanica	3.7	10	5.13	0.68	6.67
Ulmus pumila	3.6	8	4.10	0.55	6.67
Populus alba	1.7	2	1.03	0.14	3.33
Acer saccharinum	1.7	1	0.51	0.07	3.33
Pinus strobus	1.7	1	0.51	0.07	3.33
Ailanthus altissima		0			
Humulus lupulus		0			
Unrestored					
Ailanthus altissima	6.8	7	24.14	0.21	13.33
Acer rubrum	3.4	2	6.90	0.06	6.67
Humulus lupulus	1.8	7	24.14	0.21	3.33
Acer platanoides	1.7	5	17.24	0.15	3.33
Acer saccharum	1.7	4	13.79	0.12	3.33
Fraxinus americana	1.7	2	6.90	0.06	3.33
Fraxinus pennsylvanica	1.7	2	6.90	0.06	3.33
Acer negundo		0			
Acer pseudoplatanus		0			
Acer saccharinum		0			
Liriodendron tulipifera		0			
Pinus strobus		0			
Populus alba		0			
Ulmus pumila		0			

A.22. Endozoochoric species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total endozoochoric stems, percent of total stem count in restored plots, and percent of restored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Stem Count**	**% Endozoochoric Stems**	**% Total Stems**	**% of Plots**
Lindera benzoin	28.3	244	21.03	16.67	40.00
Prunus serotina	23.2	46	3.97	3.14	43.33
Rosa multiflora	22.0	157	13.53	10.72	33.33
Ampelopsis brevipedunculata	19.7	39	3.36	2.66	36.67
Toxicodendron radicans	19.5	229	19.74	15.64	23.33
Lonicera japonica	18.6	57	4.91	3.89	33.33
Lonicera maackii	16.5	44	3.79	3.01	30.00
Parthenocissus quinquefolia	13.8	13	1.12	0.89	26.67
Rubus phoenicolasius	12.7	31	2.67	2.12	23.33
Viburnum dentatum	11.5	94	8.10	6.42	16.67
Rubus pensilvanicus	9.9	46	3.97	3.14	16.67
Vitis riparia	8.0	40	3.45	2.73	13.33
Morus alba	6.9	6	0.52	0.41	13.33
Celastrus orbiculatus	5.9	25	2.16	1.71	10.00
Aronia arbutifolia	5.4	11	0.95	0.75	10.00
Sassafras albidum	5.3	10	0.86	0.68	10.00
Rubus occidentalis	5.3	8	0.69	0.55	10.00
Prunus avium	5.1	4	0.34	0.27	10.00
Rhodotypos scandens	3.6	9	0.78	0.61	6.67
Celtis occidentalis	3.6	7	0.60	0.48	6.67
Rhamnus cathartica	3.4	2	0.17	0.14	6.67
Frangula alnus	1.9	8	0.69	0.55	3.33
Cornus racemosa	1.9	7	0.60	0.48	3.33
Corylus americana	1.8	5	0.43	0.34	3.33
Hedera helix	1.8	5	0.43	0.34	3.33
Sambucus nigra	1.8	3	0.26	0.20	3.33
Nyssa sylvatica	1.7	2	0.17	0.14	3.33
Rubus odoratus	1.7	2	0.17	0.14	3.33

Amelanchier arborea	1.7	1	0.09	0.07	3.33
Broussonetia papyrifera	1.7	1	0.09	0.07	3.33
Ilex opaca	1.7	1	0.09	0.07	3.33
Rhus typhina	1.7	1	0.09	0.07	3.33
Rubus allegheniensis	1.7	1	0.09	0.07	3.33
Viburnum prunifolium	1.7	1	0.09	0.07	3.33
Euonymus alatus		0			
Ilex crenata		0			
Lonicera morrowii		0			
Rhus glabra		0			
Smilax rotundifolia		0			
Taxus baccata		0			
Viburnum dilatatum		0			
Viburnum plicatum		0			
Viburnum sieboldii		0			
Vitis aestivalis		0			
Vitis labrusca		0			
Vitis x novae-angliae		0			
Unrestored					
Rosa multiflora	63.4	999	30.78	30.08	96.67
Ampelopsis brevipedunculata	45.1	559	17.22	16.83	73.33
Lonicera japonica	41.3	308	9.49	9.27	73.33
Rubus pensilvanicus	32.9	305	9.40	9.18	56.67
Toxicodendron radicans	22.4	46	1.42	1.39	43.33
Parthenocissus quinquefolia	21.1	73	2.25	2.20	40.00
Sassafras albidum	19.0	44	1.36	1.32	36.67
Viburnum dentatum	18.3	106	3.27	3.19	33.33
Vitis aestivalis	18.1	94	2.90	2.83	33.33
Celastrus orbiculatus	12.4	268	8.26	8.07	16.67
Rubus phoenicolasius	11.0	64	1.97	1.93	20.00
Rubus occidentalis	10.5	35	1.08	1.05	20.00
Lindera benzoin	10.2	11	0.34	0.33	20.00
Smilax rotundifolia	9.0	46	1.42	1.39	16.67
Vitis labrusca	7.9	80	2.46	2.41	13.33
Celtis occidentalis	5.6	40	1.23	1.20	10.00
Lonicera maackii	5.5	31	0.96	0.93	10.00
Rubus allegheniensis	5.4	28	0.86	0.84	10.00
Lonicera morrowii	5.2	10	0.31	0.30	10.00
Vitis riparia	3.9	39	1.20	1.17	6.67
Prunus serotina	3.7	25	0.77	0.75	6.67
Sambucus nigra	3.5	9	0.28	0.27	6.67
Viburnum prunifolium	3.4	4	0.12	0.12	6.67
Rhus glabra	1.8	6	0.18	0.18	3.33

Viburnum dilatatum	1.7	5	0.15	0.15	3.33
Rhodotypos scandens	1.7	3	0.09	0.09	3.33
Ilex crenata	1.7	2	0.06	0.06	3.33
Viburnum plicatum	1.7	2	0.06	0.06	3.33
Euonymus alatus	1.7	1	0.03	0.03	3.33
Taxus baccata	1.7	1	0.03	0.03	3.33
Viburnum sieboldii	1.7	1	0.03	0.03	3.33
Vitis x novae-angliae	1.7	1	0.03	0.03	3.33
Amelanchier arborea		0			
Aronia arbutifolia		0			
Broussonetia papyrifera		0			
Cornus racemosa		0			
Corylus americana		0			
Frangula alnus		0			
Hedera helix		0			
Ilex opaca		0			
Morus alba		0			
Nyssa sylvatica		0			
Prunus avium		0			
Rhamnus cathartica		0			
Rhus typhina		0			
Rubus odoratus		0			

A.23. Species dispersed by seed hoarding in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total stems dispersed by seed hoarding, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Stem Count**	**% Seed Hoarded Stems**	**% Total Stems**	**% of Plots**
Restored					
Carya cordiformis	19.9	46	65.71	3.14	36.67
Quercus rubra	12.1	13	18.57	0.89	23.33
Quercus alba	5.2	5	7.14	0.34	10.00
Quercus montana	5.2	5	7.14	0.34	10.00
Quercus velutina	1.7	1	1.43	0.07	3.33
Juglans nigra		0			
Unrestored					
Carya cordiformis	8.5	9	81.82	0.27	16.67
Juglans nigra	1.7	1	9.09	0.03	3.33
Quercus velutina	1.7	1	9.09	0.03	3.33
Quercus alba		0			
Quercus montana		0			
Quercus rubra		0			

A.3.2.4 Pollination Syndrome of Tree Species in the Woody Understory

A.24. Abiotically pollinated species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total abiotically pollinated stems, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Abiotically Pollinated Stems	% Total Stems	% of Plots
Restored					
Fraxinus americana	27.7	79	42.93	5.40	50.0
Carya cordiformis	19.9	46	25.00	3.14	36.7
Quercus rubra	12.1	13	7.07	0.89	23.3
Fraxinus pennsylvanica	3.7	10	5.43	0.68	6.7
Celtis occidentalis	3.6	7	3.80	0.48	6.7
Morus alba	6.9	6	3.26	0.41	13.3
Corylus americana	1.8	5	2.72	0.34	3.3
Quercus alba	5.2	5	2.72	0.34	10.0
Quercus montana	5.2	5	2.72	0.34	10.0
Ostrya virginiana	1.8	3	1.63	0.20	3.3
Populus alba	1.7	2	1.09	0.14	3.3
Broussonetia papyrifera	1.7	1	0.54	0.07	3.3
Pinus strobus	1.7	1	0.54	0.07	3.3
Quercus velutina		1	0.54	0.07	3.3
Juglans nigra		0			
Taxus baccata		0			
Unrestored					
Carya cordiformis	8.5	9	16.07	0.27	16.7
Celtis occidentalis	5.6	40	71.43	1.20	10.0
Fraxinus americana	1.7	2	3.57	0.06	3.3
Fraxinus pennsylvanica	1.7	2	3.57	0.06	3.3
Juglans nigra	1.7	1	1.79	0.03	3.3
Quercus velutina	1.7	1	1.79	0.03	3.3
Taxus baccata	1.7	1	1.79	0.03	3.3
Broussonetia papyrifera		0			
Corylus americana		0			

Morus alba	0
Ostrya virginiana	0
Pinus strobus	0
Populus alba	0
Quercus alba	0
Quercus montana	0
Quercus rubra	0

A.25. Biotically pollinated species in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total biotically pollinated stems, percent of total stem count in restored, and percent of restored plots where species were sampled. Species are ranked by their IVI.

Restored

Species	**IVI**	**Stem Count**	**% Biotic Pollinated Stems**	**% Total Stems**	**% of Plots**
Lindera benzoin	28.3	244	19.24	16.67	40.0
Prunus serotina	23.2	46	3.63	3.14	43.3
Rosa multiflora	22.0	157	12.38	10.72	33.3
Ampelopsis brevipedunculata	19.7	39	3.08	2.66	36.7
Toxicodendron radicans	19.5	229	18.06	15.64	23.3
Lonicera japonica	18.6	57	4.50	3.89	33.3
Lonicera maackii	16.5	44	3.47	3.01	30.0
Parthenocissus quinquefolia	13.8	13	1.03	0.89	26.7
Rubus phoenicolasius	12.7	31	2.44	2.12	23.3
Viburnum dentatum	11.5	94	7.41	6.42	16.7
Acer pseudoplatanus	10.7	20	1.58	1.37	20.0
Acer platanoides	10.3	10	0.79	0.68	20.0
Rubus pensilvanicus	9.9	46	3.63	3.14	16.7
Acer negundo	9.5	34	2.68	2.32	16.7
Acer saccharum	8.9	17	1.34	1.16	16.7
Liriodendron tulipifera	8.5	6	0.47	0.41	16.7
Vitis riparia	8.0	40	3.15	2.73	13.3
Acer rubrum	6.9	7	0.55	0.48	13.3
Celastrus orbiculatus	5.9	25	1.97	1.71	10.0
Ligustrum obtusifolium	5.9	25	1.97	1.71	10.0
Aronia arbutifolia	5.4	11	0.87	0.75	10.0
Sassafras albidum	5.3	10	0.79	0.68	10.0
Rubus occidentalis	5.3	8	0.63	0.55	10.0
Prunus avium	5.1	4	0.32	0.27	10.0
Rhodotypos scandens	3.6	9	0.71	0.61	6.7

Rhamnus cathartica	3.4	2	0.16	0.14	6.7
Frangula alnus	1.9	8	0.63	0.55	3.3
Cornus racemosa	1.9	7	0.55	0.48	3.3
Forsythia xintermedia	1.9	6	0.47	0.41	3.3
Hedera helix	1.8	5	0.39	0.34	3.3
Sambucus nigra	1.8	3	0.24	0.20	3.3
Philadelphus lewisii	1.7	2	0.16	0.14	3.3
Rubus odoratus	1.7	2	0.16	0.14	3.3
Acer saccharinum	1.7	1	0.08	0.07	3.3
Amelanchier arborea	1.7	1	0.08	0.07	3.3
Clethra alnifolia	1.7	1	0.08	0.07	3.3
Ilex opaca	1.7	1	0.08	0.07	3.3
Rhus typhina	1.7	1	0.08	0.07	3.3
Rubus allegheniensis	1.7	1	0.08	0.07	3.3
Viburnum prunifolium	1.7	1	0.08	0.07	3.3
Ailanthus altissima		0			
Euonymus alatus		0			
Humulus lupulus		0			
Ilex crenata		0			
Lonicera morrowii		0			
Rhus glabra		0			
Robinia pseudoacacia		0			
Smilax rotundifolia		0			
Viburnum dilatatum		0			
Viburnum plicatum		0			
Viburnum sieboldii		0			
Vitis aestivalis		0			
Vitis labrusca		0			
Vitis x novae-angliae		0			
Wisteria sinensis		0			
Unrestored					
Rosa multiflora	63.4	999	30.76	30.08	96.7
Ampelopsis brevipedunculata	45.1	559	17.21	16.83	73.3
Lonicera japonica	41.3	308	9.48	9.27	73.3
Celastrus orbiculatus	39.0	268	8.25	8.07	70.0
Rubus pensilvanicus	32.9	305	9.39	9.18	56.7
Toxicodendron radicans	22.4	46	1.42	1.39	43.3
Parthenocissus quinquefolia	21.1	73	2.25	2.20	40.0
Sassafras albidum	19.0	44	1.35	1.32	36.7

Viburnum dentatum	18.3	106	3.26	3.19	33.3
Vitis aestivalis	18.1	94	2.89	2.83	33.3
Rubus phoenicolasius	11.0	64	1.97	1.93	20.0
Rubus occidentalis	10.5	35	1.08	1.05	20.0
Lindera benzoin	10.2	11	0.34	0.33	20.0
Smilax rotundifolia	9.0	46	1.42	1.39	16.7
Vitis labrusca	7.9	80	2.46	2.41	13.3
Ailanthus altissima	6.8	7	0.22	0.21	13.3
Lonicera maackii	5.5	31	0.95	0.93	10.0
Rubus allegheniensis	5.4	28	0.86	0.84	10.0
Lonicera morrowii	5.2	10	0.31	0.30	10.0
Vitis riparia	3.9	39	1.20	1.17	6.7
Prunus serotina	3.7	25	0.77	0.75	6.7
Sambucus nigra	3.5	9	0.28	0.27	6.7
Ligustrum obtusifolium	3.4	7	0.22	0.21	6.7
Viburnum prunifolium	3.4	4	0.12	0.12	6.7
Acer rubrum	3.4	2	0.06	0.06	6.7
Wisteria sinensis	1.8	10	0.31	0.30	3.3
Humulus lupulus	1.8	7	0.22	0.21	3.3
Rhus glabra	1.8	6	0.18	0.18	3.3
Acer platanoides	1.7	5	0.15	0.15	3.3
Viburnum dilatatum	1.7	5	0.15	0.15	3.3
Acer saccharum	1.7	4	0.12	0.12	3.3
Rhodotypos scandens	1.7	3	0.09	0.09	3.3
Ilex crenata	1.7	2	0.06	0.06	3.3
Viburnum plicatum	1.7	2	0.06	0.06	3.3
Euonymus alatus	1.7	1	0.03	0.03	3.3
Robinia pseudoacacia	1.7	1	0.03	0.03	3.3
Viburnum sieboldii	1.7	1	0.03	0.03	3.3
Vitis x novae-angliae	1.7	1	0.03	0.03	3.3
Acer negundo		0			
Acer pseudoplatanus		0			
Acer saccharinum		0			
Amelanchier arborea		0			
Aronia arbutifolia		0			
Clethra alnifolia		0			
Cornus racemosa		0			
Forsythia xintermedia		0			
Frangula alnus		0			
Hedera helix		0			

Ilex opaca	0
Liriodendron tulipifera	0
Philadelphus lewisii	0
Prunus avium	0
Rhamnus cathartica	0
Rhus typhina	0
Rubus odoratus	0

A.3.2.5 Lifespan of Tree Species in the Woody Understory

A.26. Tree species with long lifespan in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total tree stems with long lifespan, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored **Species**	**Stem Count**	**IVI**	**% Long Lifespan Stems**	**% Total Stems**	**% of Plots**
Quercus rubra	13	12.1	37.14	0.89	23.33
Acer saccharum	17	8.9	48.57	1.16	16.67
Quercus alba	5	5.2	14.29	0.34	10.00
Unrestored					
Acer saccharum	4	1.7	100.00	0.12	3.33
Quercus alba	0				
Quercus rubra	0				

A.27. Tree species with moderate lifespan in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total tree stems with moderate lifespan, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Moderate Lifespan Stems	% Total Stems	% of Plots
Restored					
Fraxinus americana	27.7	79	36.57	5.40	50.00
Prunus serotina	23.2	46	21.30	3.14	43.33
Carya cordiformis	19.9	46	21.30	3.14	36.67
Acer pseudoplatanus	10.7	20	9.26	1.37	20.00
Liriodendron tulipifera	8.5	6	2.78	0.41	16.67
Morus alba	6.9	6	2.78	0.41	13.33
Celtis occidentalis	3.6	7	3.24	0.48	6.67
Nyssa sylvatica	1.7	2	0.93	0.14	3.33
Populus alba	1.7	2	0.93	0.14	3.33
Pinus strobus	1.7	1	0.46	0.07	3.33
Quercus velutina	1.7	1	0.46	0.07	3.33
Juglans nigra		0			
Unrestored					
Carya cordiformis	8.6	18	11.61	0.54	16.67
Celtis occidentalis	6.2	79	50.97	2.38	10.00
Prunus serotina	4.1	50	32.26	1.51	6.67
Fraxinus americana	1.7	4	2.58	0.12	3.33
Juglans nigra	1.7	2	1.29	0.06	3.33
Quercus velutina	1.7	2	1.29	0.06	3.33
Acer pseudoplatanus		0			
Liriodendron tulipifera		0			
Morus alba		0			
Nyssa sylvatica		0			
Pinus strobus		0			
Populus alba		0			

A.28. Tree species with short lifespan in the woody understory of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total stem count, percent of total tree stems with short lifespan, percent of total stem count in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Stem Count	% Short Lifespan Stems	% Total Stems	% of Plots
Restored					
Acer platanoides	10.3	10	11.49	0.68	20.00
Acer negundo	9.5	34	39.08	2.32	16.67
Acer rubrum	6.9	7	8.05	0.48	13.33
Sassafras albidum	5.3	10	11.49	0.68	10.00
Prunus avium	5.1	4	4.60	0.27	10.00
Fraxinus pennsylvanica	3.7	10	11.49	0.68	6.67
Ulmus pumila	3.6	8	9.20	0.55	6.67
Ostrya virginiana	1.8	3	3.45	0.20	3.33
Acer saccharinum	1.7	1	1.15	0.07	3.33
Ailanthus altissima		0			
Robinia pseudoacacia		0			
Unrestored					
Sassafras albidum	19.0	44	72.13	1.32	36.67
Ailanthus altissima	6.8	7	11.48	0.21	13.33
Acer rubrum	3.4	2	3.28	0.06	6.67
Acer platanoides	1.7	5	8.20	0.15	3.33
Fraxinus pennsylvanica	1.7	2	3.28	0.06	3.33
Robinia pseudoacacia	1.7	1	1.64	0.03	3.33
Acer negundo		0			
Acer saccharinum		0			
Ostrya virginiana		0			
Prunus avium		0			
Ulmus pumila		0			

A.3.3 Woody Species in the Ground Layer

A.3.3.1 Growth Forms of Woody Species in the Ground Layer

A. 29. Tree species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Cover (cm)**	**% Woody Species Cover**	**% Total Cover**	**% of Plots**
Prunus serotina	33.0	349	9.40	0.82	56.67
Fraxinus pennsylvanica	24.5	829	22.33	1.95	26.67
Carya cordiformis	24.4	450	12.12	1.06	36.67
Acer pseudoplatanus	14.7	472	12.71	1.11	16.67
Acer platanoides	11.6	242	6.52	0.57	16.67
Sassafras albidum	10.3	393	10.58	0.93	10
Acer negundo	7.3	170	4.58	0.40	10
Acer saccharum	7.1	155	4.17	0.37	10
Quercus rubra	6.0	75	2.02	0.18	10
Prunus avium	5.2	259	6.98	0.61	3.33
Liriodendron tulipifera	4.7	104	2.80	0.24	6.67
Quercus alba	4.1	59	1.59	0.14	6.67
Celtis occidentalis	3.6	19	0.51	0.04	6.67
Acer saccharinum	3.5	13	0.35	0.03	6.67
Populus alba	2.6	73	1.97	0.17	3.33
Quercus montana	2.2	40	1.08	0.09	3.33
Broussonetia papyrifera	1.8	10	0.27	0.02	3.33
Cornus florida	1.7	1	0.03	0.00	3.33
Acer rubrum	0.0				
Ailanthus altissima	0.0				
Fraxinus americana	0.0				
Ilex crenata	0.0				
Juglans nigra	0.0				
Liquidambar styraciflua	0.0				

Morus alba	0.0				
Quercus palustris	0.0				
Quercus velutina	0.0				
Robinia pseudoacacia	0.0				
Tilia americana	0.0				
Unrestored					
Sassafras albidum	42.21	1190	34.41	0.95	50.00
Prunus serotina	30.16	818	23.66	0.66	36.67
Carya cordiformis	13.94	157	4.54	0.13	23.33
Morus alba	9.72	211	6.10	0.17	13.33
Robinia pseudoacacia	7.62	66	1.91	0.05	13.33
Juglans nigra	6.58	109	3.15	0.09	10.00
Acer rubrum	6.05	188	5.44	0.15	6.67
Quercus velutina	5.68	47	1.36	0.04	10.00
Quercus rubra	5.62	43	1.24	0.03	10.00
Acer saccharum	4.49	195	5.64	0.16	3.33
Fraxinus americana	4.42	75	2.17	0.06	6.67
Liquidambar styraciflua	4.06	50	1.45	0.04	6.67
Acer platanoides	3.93	41	1.19	0.03	6.67
Ailanthus altissima	3.56	16	0.46	0.01	6.67
Ilex crenata	3.39	119	3.44	0.10	3.33
Tilia americana	2.39	50	1.45	0.04	3.33
Quercus palustris	2.11	31	0.90	0.02	3.33
Acer pseudoplatanus	2.03	25	0.72	0.02	3.33
Cornus florida	1.88	15	0.43	0.01	3.33
Fraxinus pennsylvanica	1.84	12	0.35	0.01	3.33
Acer negundo	0.00				
Acer saccharinum	0.00				
Broussonetia papyrifera	0.00				
Celtis occidentalis	0.00				
Liriodendron tulipifera	0.00				
Populus alba	0.00				
Prunus avium	0.00				
Quercus alba	0.00				
Quercus montana	0.00				

A.30. Shrub species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Cover (cm)**	**% Woody Species Cover**	**% Total Cover**	**% of Plots**
Rosa multiflora	36.1	1527	18.92	3.60	53.33
Lindera benzoin	31.0	1771	21.95	4.17	40.00
Rubus phoenicolasius	23.7	872	10.81	2.06	36.67
Viburnum dentatum	19.6	473	5.86	1.11	33.33
Rubus pensilvanicus	17.8	1262	15.64	2.97	20.00
Lonicera maackii	10.2	308	3.82	0.73	16.67
Rubus occidentalis	9.9	245	3.04	0.58	16.67
Rubus allegheniensis	6.8	553	6.85	1.30	6.67
Rubus flagellaris	4.6	201	2.49	0.47	6.67
Frangula alnus	3.6	37	0.46	0.09	6.67
Pachysandra terminalis	3.5	32	0.40	0.08	6.67
Philadelphus coronarius	2.7	162	2.01	0.38	3.33
Rhus typhina	2.5	138	1.71	0.33	3.33
Vinca minor	2.5	132	1.64	0.31	3.33
Ligustrum obtusifolium	2.5	128	1.59	0.30	3.33
Clethra alnifolia	2.3	100	1.24	0.24	3.33
Rubus odoratus	2.1	67	0.83	0.16	3.33
Viburnum prunifolium	2.0	55	0.68	0.13	3.33
Crataegus monogyna	1.7	6	0.07	0.01	3.33
Cornus amomum		0			
Corylus americana		0			
Ilex verticillata		0			
Lonicera morrowii		0			
Rhodotypos scandens		0			
Sambucus nigra		0			
Taxus baccata		0			
Viburnum dilatatum		0			
Viburnum opulus		0			
Viburnum sieboldii		0			

Unrestored					
Rosa multiflora	83.9	30408	71.08	24.40	96.67
Rubus pensilvanicus	41.3	5406	12.64	4.34	70.00
Viburnum dentatum	21.2	1026	2.40	0.82	40.00
Rubus phoenicolasius	17.3	1940	4.53	1.56	30.00
Rubus flagellaris	11.9	235	0.55	0.19	23.33
Lonicera maackii	10.5	395	0.92	0.32	20.00
Lindera benzoin	8.8	371	0.87	0.30	16.67
Rubus occidentalis	7.0	249	0.58	0.20	13.33
Viburnum prunifolium	5.3	299	0.70	0.24	10.00
Rubus allegheniensis	5.2	137	0.32	0.11	10.00
Philadelphus coronarius	4.2	759	1.77	0.61	6.67
Lonicera morrowii	4.0	551	1.29	0.44	6.67
Ligustrum obtusifolium	3.5	156	0.36	0.13	6.67
Rhodotypos scandens	3.4	95	0.22	0.08	6.67
Frangula alnus	3.4	46	0.11	0.04	6.67
Viburnum dilatatum	1.9	228	0.53	0.18	3.33
Sambucus nigra	1.8	135	0.32	0.11	3.33
Taxus baccata	1.8	93	0.22	0.07	3.33
Viburnum opulus	1.8	83	0.19	0.07	3.33
Cornus amomum	1.8	75	0.18	0.06	3.33
Corylus americana	1.7	47	0.11	0.04	3.33
Viburnum sieboldii	1.7	36	0.08	0.03	3.33
Ilex verticillata	1.7	12	0.03	0.01	3.33
Clethra alnifolia		0			
Crataegus monogyna		0			
Pachysandra terminalis		0			
Rhus typhina		0			
Rubus odoratus		0			
Vinca minor		0			

A.31. Vine species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Woody Species Cover**	**% Total Cover**	**% of Plots**
Restored					
Toxicodendron radicans	54.17	3758	28.34	8.86	80.00
Parthenocissus quinquefolia	50.99	2915	21.98	6.87	80.00
Lonicera japonica	36.27	2988	22.53	7.04	50.00
Ampelopsis brevipedunculata	26.77	912	6.88	2.15	46.67
Hedera helix	9.94	1310	9.88	3.09	10.00
Celastrus orbiculatus	8.40	459	3.46	1.08	13.33
Vitis riparia	7.88	322	2.43	0.76	13.33
Smilax rotundifolia	3.91	153	1.15	0.36	6.67
Wisteria sinensis	1.86	52	0.39	0.12	3.33
Rubus laciniatus	1.78	30	0.23	0.07	3.33
Vitis x novae-angliae	1.68	4	0.03	0.01	3.33
Clematis virginiana		0			
Vitis aestivalis		0			
Vitis labrusca		0			
Unrestored					
Ampelopsis brevipedunculata	60.07	24214	40.14	19.43	80.00
Parthenocissus quinquefolia	50.63	4787	7.94	3.84	93.33
Lonicera japonica	48.69	8474	14.05	6.80	83.33
Celastrus orbiculatus	48.19	9882	16.38	7.93	80.00
Toxicodendron radicans	40.23	4305	7.14	3.45	73.33
Vitis aestivalis	21.68	4038	6.69	3.24	36.67

Smilax rotundifolia	10.42	503	0.83	0.40	20.00
Vitis labrusca	10.01	2020	3.35	1.62	16.67
Vitis riparia	4.38	1260	2.09	1.01	6.67
Hedera helix	3.36	27	0.04	0.02	6.67
Wisteria sinensis	1.86	235	0.39	0.19	3.33
Clematis virginiana	1.67	8	0.01	0.01	3.33
Rubus laciniatus	0.00	0	0.00	0.00	0.00
Vitis x novae-angliae	0.00	0	0.00	0.00	0.00

A.3.3.2 Shade Tolerance of Woody Species in the Ground Layer

A.32. Shade tolerant woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among shade tolerant woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Shade Tolerant Cover**	**%Total Cover**	**% of Plots**
Restored					
Lonicera japonica	28.5	2988	35.37	7.04	50.00
Fraxinus pennsylvanica	14.3	829	9.81	1.95	26.67
Rubus pensilvanicus	11.5	1262	14.94	2.97	20.00
Celastrus orbiculatus	7.2	459	5.43	1.08	13.33
Hedera helix	6.5	1310	15.50	3.09	10.00
Acer negundo	5.2	170	2.01	0.40	10.00
Acer saccharum	5.2	155	1.83	0.37	10.00
Rubus allegheniensis	4.0	553	6.55	1.30	6.67
Celtis occidentalis	3.4	19	0.16	0.04	6.67
Pachysandra terminalis	3.4	32	0.38	0.08	6.67
Vinca minor	1.8	132	1.56	0.31	3.33
Viburnum prunifolium	1.7	55	0.65	0.13	3.33
Rubus laciniatus	1.7	30	0.36	0.07	3.33
Cornus florida	1.7	1	0.01	0.00	3.33
Ilex crenata		0			
Lonicera morrowii		0			
Rhodotypos scandens		0			
Taxus baccata		0			
Tilia americana		0			
Viburnum opulus		0			
Vitis aestivalis		0			
Unrestored					
Lonicera japonica	45.1	8474	27.81	6.80	83.33
Celastrus orbiculatus	44.0	9882	32.44	7.93	80.00
Rubus pensilvanicus	37.2	5406	17.74	4.34	70.00
Vitis aestivalis	20.0	4038	13.25	3.24	36.67

Viburnum prunifolium	5.1	299	0.98	0.24	10.00
Rubus allegheniensis	5.1	137	0.45	0.11	10.00
Lonicera morrowii	3.6	551	1.81	0.44	6.67
Rhodotypos scandens	3.4	95	0.31	0.08	6.67
Hedera helix	3.3	27	0.09	0.02	6.67
Acer saccharum	1.7	195	0.64	0.16	3.33
Ilex crenata	1.7	119	0.39	0.10	3.33
Taxus baccata	1.7	93	0.31	0.07	3.33
Tilia americana	1.7	50	0.16	0.04	3.33
Cornus florida	1.7	15	0.05	0.01	3.33
Viburnum opulus	1.7	83	0.21	0.07	3.33
Fraxinus pennsylvanica	1.7	12	0.04	0.01	3.33
Acer negundo		0			
Celtis occidentalis		0			
Pachysandra terminalis		0			
Rubus laciniatus		0			
Vinca minor		0			

A. 33. Woody species with intermediate shade tolerance in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among intermediate shade tolerant woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Cover (cm)**	**% Intermediate Shade Tolerant Cover**	**% Total Cover**	**% of Plots**
Toxicodendron radicans	44.4	3758	31.30	8.86	80.00
Parthenocissus quinquefolia	43.4	2915	24.28	6.87	80.00
Ampelopsis brevipedunculata	24.4	912	7.59	2.15	46.67
Lindera benzoin	22.1	1771	14.75	4.17	40.00
Rubus phoenicolasius	19.4	872	7.26	2.06	36.67
Viburnum dentatum	17.2	473	5.60	1.11	33.33
Lonicera maackii	8.7	308	7.29	0.73	16.67
Rubus occidentalis	8.6	245	2.04	0.58	16.67
Acer platanoides	8.6	242	2.02	0.57	16.67
Vitis riparia	7.0	322	2.68	0.76	13.33
Quercus rubra	5.1	75	0.62	0.18	10.00
Rubus flagellaris	3.6	201	1.67	0.47	6.67
Quercus alba	3.4	59	0.49	0.14	6.67
Acer saccharinum	3.3	13	0.11	0.03	6.67
Prunus avium	2.0	259	2.16	0.61	3.33
Ligustrum obtusifolium	1.8	128	1.07	0.30	3.33
Clethra alnifolia	1.8	100	0.83	0.24	3.33
Rubus odoratus	1.7	67	0.56	0.16	3.33
Quercus montana	1.7	40	0.33	0.09	3.33
Wisteria sinensis	1.7	52	1.23	0.12	3.33
Acer rubrum		0			
Clematis virginiana		0			
Cornus amomum		0			
Corylus americana		0			

Ilex verticillata		0			
Morus alba		0			
Quercus velutina		0			
Viburnum dilatatum		0			
Viburnum sieboldii		0			
Vitis labrusca		0			
Unrestored					
Ampelopsis brevipedunculata	49.7	24214	62.69	19.43	80.00
Parthenocissus quinquefolia	48.6	4787	12.39	3.84	93.33
Toxicodendron radicans	38.4	4305	11.15	3.45	73.33
Viburnum dentatum	20.4	1026.00	3.37	0.82	40.00
Rubus phoenicolasius	15.8	1940	5.02	1.56	30.00
Rubus flagellaris	11.8	235	0.61	0.19	23.33
Lonicera maackii	10.2	395	1.07	0.32	20.00
Vitis labrusca	9.1	2020	5.47	1.62	16.67
Lindera benzoin	8.5	371	0.96	0.30	16.67
Rubus occidentalis	6.8	249	0.64	0.20	13.33
Morus alba	6.8	211	0.55	0.17	13.33
Quercus rubra	5.0	43	0.11	0.03	10.00
Quercus velutina	5.0	47.00	0.15	0.04	10.00
Vitis riparia	3.8	1260	3.26	1.01	6.67
Acer rubrum	3.4	188	0.49	0.15	6.67
Ligustrum obtusifolium	3.4	156	0.40	0.13	6.67
Acer platanoides	3.3	41	0.11	0.03	6.67
Wisteria sinensis	1.8	235	0.64	0.19	3.33
Viburnum dilatatum	1.8	228	0.59	0.18	3.33
Cornus amomum	1.7	75	0.19	0.06	3.33
Corylus americana	1.7	47	0.12	0.04	3.33
Viburnum sieboldii	1.7	36	0.09	0.03	3.33
Ilex verticillata	1.7	12	0.03	0.01	3.33
Clematis virginiana	1.7	8	0.02	0.01	3.33
Acer saccharinum		0			
Clethra alnifolia		0			
Prunus avium		0			
Quercus alba		0			
Quercus montana		0			
Rubus odoratus		0			

A.34. Shade intolerant woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among shade intolerant woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Shade Intolerant Cover	%Total Cover	% of Plots
Restored					
Prunus serotina	28.7	349	8.26	0.82	56.67
Rosa multiflora	28.5	1527	36.15	3.60	53.33
Carya cordiformis	18.9	450	10.65	1.06	36.67
Acer pseudoplatanus	8.9	472	11.17	1.11	16.67
Sassafras albidum	5.5	393	9.30	0.93	10.00
Smilax rotundifolia	3.5	153	3.62	0.36	6.67
Liriodendron tulipifera	3.5	104	2.46	0.25	6.67
Frangula alnus	3.4	37	0.88	0.09	6.67
Philadelphus coronarius	1.9	162	3.84	0.38	3.33
Rhus typhina	1.8	138	3.27	0.33	3.33
Populus alba	1.8	73	1.73	0.17	3.33
Broussonetia papyrifera	1.7	10	0.08	0.02	3.33
Crataegus monogyna	1.7	6	0.14	0.01	3.33
Ailanthus altissima		0			
Fraxinus americana		0			
Juglans nigra		0			
Liquidambar styraciflua		0			
Quercus palustris		0			
Robinia pseudoacacia		0			
Sambucus nigra		0			
Unrestored					
Rosa multiflora	60.5	30408	82.40	24.40	96.67
Sassafras albidum	25.5	1190	3.22	0.95	50.00
Prunus serotina	18.7	818	2.22	0.66	36.67
Carya cordiformis	11.7	157	0.43	0.13	23.33
Smilax rotundifolia	10.2	503	1.36	0.40	20.00
Robinia pseudoacacia	6.7	66	0.18	0.05	13.33

Juglans nigra	5.0	109	0.30	0.09	10.00
Philadelphus coronarius	3.6	759	2.06	0.61	6.67
Fraxinus americana	3.4	75	0.20	0.06	6.67
Liquidambar styraciflua	3.4	50	0.14	0.04	6.67
Frangula alnus	3.4	46	0.12	0.04	6.67
Ailanthus altissima	3.3	16	0.04	0.01	6.67
Quercus palustris	1.7	31	0.08	0.02	3.33
Acer pseudoplatanus	1.7	25	0.07	0.02	3.33
Sambucus nigra	1.7	135	0.35	0.11	3.33
Broussonetia papyrifera		0			
Crataegus monogyna		0			
Liriodendron tulipifera		0			
Populus alba		0			
Rhus typhina		0			

A.3.3.3 Seed Dispersal of Woody Species in the Ground Layer

A.35. Wind dispersed woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among wind dispersed woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Wind Dispersal Cover**	**% Total Cover**	**% of Plots**
Restored					
Fraxinus pennsylvanica	14.3	829	40.28	1.95	26.67
Acer pseudoplatanus	8.9	472	22.93	1.11	16.67
Acer platanoides	8.6	242	11.76	0.57	16.67
Acer negundo	5.2	170	8.26	0.40	10.00
Acer saccharum	5.2	155	7.53	0.37	10.00
Liriodendron tulipifera	3.5	104	5.05	0.25	6.67
Acer saccharinum	3.3	13	0.63	0.03	6.67
Populus alba	1.8	73	3.55	0.17	3.33
Acer rubrum		0			
Ailanthus altissima		0			
Clematis virginiana		0			
Fraxinus americana		0			
Liquidambar styraciflua		0			
Unrestored					
Acer rubrum	3.4	188	30.82	0.15	6.67
Fraxinus americana	3.4	75	12.30	0.06	6.67
Liquidambar styraciflua	3.4	50	8.20	0.04	6.67
Acer platanoides	3.3	41	6.72	0.03	6.67

Ailanthus altissima	3.3	16	2.62	0.01	6.67
Acer saccharum	1.7	195	31.97	0.16	3.33
Acer pseudoplatanus	1.7	25	4.10	0.02	3.33
Fraxinus pennsylvanica	1.7	12	1.97	0.01	3.33
Clematis virginiana	1.7	8	1.31	0.01	3.33
Acer negundo		0			
Acer saccharinum		0			
Liriodendron tulipifera		0			
Populus alba		0			

A. 36. Woody species with unassisted seed dispersal in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among woody species with unassisted seed dispersal in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Unassisted Dispersal Cover	% Total Cover	% of Plots
Restored					
Philadelphus coronarius	1.9	162	41.54	0.38	3.33
Ligustrum obtusifolium	1.8	128	32.82	0.30	3.33
Clethra alnifolia	1.8	100	25.64	0.24	3.33
Robinia pseudoacacia		0			
Unrestored					
Robinia pseudoacacia	6.7	66	6.40	0.05	13.33
Philadelphus coronarius	3.6	759	73.62	0.61	6.67
Ligustrum obtusifolium	3.4	156	15.13	0.13	6.67
Clethra alnifolia		0			

A.37. Endozoochoric woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover among endozoochoric woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Endozoochoric Cover	% Total Cover	% of Plots
Restored					
Toxicodendron radicans	44.4	3758	17.54	8.86	80.00
Parthenocissus quinquefolia	43.4	2915	13.60	6.87	80.00
Prunus serotina	28.7	349	1.63	0.82	56.67
Lonicera japonica	28.5	2988	13.94	7.04	50.00
Rosa multiflora	28.5	1527	7.13	3.60	53.33
Ampelopsis brevipedunculata	24.4	912	4.26	2.15	46.67
Lindera benzoin	22.1	1771	8.26	4.17	40.00
Rubus phoenicolasius	19.4	872	4.07	2.06	36.67
Viburnum dentatum	17.2	473	2.21	1.11	33.33
Rubus pensilvanicus	11.5	1262	5.89	2.97	20.00
Lonicera maackii	8.7	308	1.44	0.73	16.67
Rubus occidentalis	8.6	245	1.14	0.58	16.67
Celastrus orbiculatus	7.2	459	2.14	1.08	13.33
Vitis riparia	7.0	322	1.50	0.76	13.33
Hedera helix	6.5	1310	6.11	3.09	10.00
Sassafras albidum	5.5	393	1.83	0.93	10.00
Rubus allegheniensis	4.0	553	2.58	1.30	6.67
Rubus flagellaris	3.6	201	0.94	0.47	6.67
Smilax rotundifolia	3.5	153	0.71	0.36	6.67
Frangula alnus	3.4	37	0.17	0.09	6.67
Pachysandra terminalis	3.4	32	0.15	0.08	6.67
Celtis occidentalis	3.4	19	0.09	0.04	6.67
Prunus avium	2.0	259	1.21	0.61	3.33
Rhus typhina	1.8	138	0.64	0.33	3.33
Rubus odoratus	1.7	67	0.31	0.16	3.33

Viburnum prunifolium	1.7	55	0.26	0.13	3.33
Rubus laciniatus	1.7	30	0.14	0.07	3.33
Broussonetia papyrifera	1.7	10	0.05	0.02	3.33
Crataegus monogyna	1.7	6	0.03	0.01	3.33
Vitis x novae-angliae	1.7	4	0.02	0.01	3.33
Cornus florida	1.7	1	0.005	0.002	3.33
Cornus amomum		0			
Corylus americana		0			
Ilex crenata		0			
Ilex verticillata		0			
Lonicera morrowii		0			
Morus alba		0			
Rhodotypos scandens		0			
Sambucus nigra		0			
Taxus baccata		0			
Viburnum dilatatum		0			
Viburnum opulus		0			
Viburnum sieboldii		0			
Vitis aestivalis		0			
Vitis labrusca		0			
Unrestored					
Rosa multiflora	60.5	30408	29.31	24.40	96.67
Ampelopsis brevipedunculata	49.7	24214	23.34	19.43	80.00
Parthenocissus quinquefolia	48.6	4787	4.61	3.84	93.33
Lonicera japonica	45.1	8474	8.17	6.80	83.33
Celastrus orbiculatus	44.0	9882	9.53	7.93	80.00
Toxicodendron radicans	38.4	4305	4.15	3.45	73.33
Rubus pensilvanicus	37.2	5406	5.21	4.34	70.00
Sassafras albidum	25.5	1190	1.15	0.95	50.00
Viburnum dentatum	20.4	1026	0.99	0.82	40.00
Vitis aestivalis	20.0	4038	3.89	3.24	36.67
Prunus serotina	18.7	818	0.79	0.66	36.67
Rubus phoenicolasius	15.8	1940	1.87	1.56	30.00
Rubus flagellaris	11.8	235	0.23	0.19	23.33
Smilax rotundifolia	10.2	503	0.48	0.40	20.00
Lonicera maackii	10.2	395	0.38	0.32	20.00
Vitis labrusca	9.1	2020	1.95	1.62	16.67
Lindera benzoin	8.5	371	0.36	0.30	16.67
Rubus occidentalis	6.8	249	0.24	0.20	13.33

Morus alba	6.8	211	0.20	0.17	13.33
Viburnum prunifolium	5.1	299	0.29	0.24	10.00
Rubus allegheniensis	5.1	137	0.13	0.11	10.00
Vitis riparia	3.8	1260	1.21	1.01	6.67
Lonicera morrowii	3.6	551	0.53	0.44	6.67
Rhodotypos scandens	3.4	95	0.09	0.08	6.67
Frangula alnus	3.4	46	0.04	0.04	6.67
Hedera helix	3.3	27	0.03	0.02	6.67
Viburnum dilatatum	1.8	228	0.22	0.18	3.33
Sambucus nigra	1.7	135	0.13	0.11	3.33
Ilex crenata	1.7	119	0.11	0.10	3.33
Taxus baccata	1.7	93	0.09	0.07	3.33
Viburnum opulus	1.7	83	0.08	0.07	3.33
Cornus amomum	1.7	75	0.07	0.06	3.33
Corylus americana	1.7	47	0.05	0.04	3.33
Viburnum sieboldii	1.7	36	0.03	0.03	3.33
Cornus florida	1.7	15	0.01	0.01	3.33
Ilex verticillata	1.7	12	0.01	0.01	3.33
Broussonetia papyrifera		0			
Celtis occidentalis		0			
Crataegus monogyna		0			
Pachysandra terminalis		0			
Prunus avium		0			
Rhus typhina		0			
Rubus laciniatus		0			
Rubus odoratus		0			
Vitis x novae-angliae		0			

A.38. Woody species dispersed by seed hoarding in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by woody species dispersed by hoarding in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Hoarding Cover**	**% Total Cover**	**% of Plots**
Restored					
Carya cordiformis	**18.9**	450	72.12	1.06	36.67
Quercus rubra	**5.1**	75	12.02	0.18	10.00
Quercus alba	**3.4**	59	9.46	0.14	6.67
Quercus montana	**1.7**	40	6.41	0.09	3.33
Juglans nigra		0			
Quercus palustris		0			
Quercus velutina		0			
Unrestored					
Carya cordiformis	**11.7**	157	40.57	0.13	23.33
Juglans nigra	**5.0**	109	28.17	0.09	10.00
Quercus velutina	**5.0**	47	12.14	0.04	10.00
Quercus rubra	**5.0**	43	11.11	0.03	10.00
Quercus palustris	**1.7**	31	8.01	0.02	3.33
Quercus alba		0			
Quercus montana		0			

A.39. Ant dispersed woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by woody species dispersed by ants in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

	Species	IVI	Cover (cm)	% Ant Cover	% Total Cover	% of Plots
Restored	*Vinca minor*	1.8	132	100.00	0.31	3.33
Unrestored	*Vinca minor*		0	0	0.00	0.00

A.40 . Woody species dispersed by other dispersal modes, these modes included dispersal by water and launching, in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by woody species dispersed by other modes in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

	Species	IVI	Cover (cm)	% Other Dispersal Cover	% Total Cover	% of Plots
Restored	*Wisteria sinensis*	1.7	52	100	0.12	3.33
Unrestored	*Wisteria sinensis*	1.8	235	100.00	0.19	3.33

A.3.3.4. Pollination Syndromes of Woody Species in the Ground Layer

A.41. Abiotically pollinated woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by abiotically pollinated woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Abiotic Pollination Cover	% Total Cover	% of Plots
Restored					
Carya cordiformis	18.9	450	28.94	1.06	36.67
Fraxinus pennsylvanica	14.3	829	53.31	1.95	26.67
Quercus rubra	5.1	75	4.82	0.18	10.00
Quercus alba	3.4	59	3.79	0.14	6.67
Celtis occidentalis	3.4	19	1.22	0.04	6.67
Populus alba	1.8	73	4.69	0.17	3.33
Quercus montana	1.7	40	2.57	0.09	3.33
Broussonetia papyrifera	1.7	10	0.64	0.02	3.33
Corylus americana		0			
Fraxinus americana		0			
Juglans nigra		0			
Morus alba		0			
Quercus palustris		0			
Quercus velutina		0			
Taxus baccata		0			
Unrestored					
Quercus rubra	5.0	43	5.21	0.03	10.00
Carya cordiformis	11.7	157	19.03	0.13	23.33
Quercus velutina	5.0	47	5.70	0.04	10.00
Morus alba	6.8	211	25.58	0.17	13.33
Taxus baccata	1.7	93	11.27	0.07	3.33
Fraxinus americana	3.4	75	9.09	0.06	6.67
Juglans nigra	5.0	109	13.21	0.09	10.00
Corylus americana	1.7	47	5.70	0.04	3.33
Quercus palustris	1.7	31	3.76	0.02	3.33
Fraxinus pennsylvanica	1.7	12	1.45	0.01	3.33

Broussonetia papyrifera	0
Celtis occidentalis	0
Populus alba	0
Quercus alba	0
Quercus montana	0

A.42. Biotically pollinated woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by biotically pollinated woody species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Biotic Pollination Cover	% Total Cover	% of Plots
Restored					
Toxicodendron radicans	44.4	3758	16.36	8.86	80.00
Parthenocissus quinquefolia	43.4	2915	12.69	6.87	80.00
Prunus serotina	28.7	349	1.52	0.82	56.67
Lonicera japonica	28.5	2988	13.01	7.04	50.00
Rosa multiflora	28.5	1527	6.65	3.60	53.33
Ampelopsis brevipedunculata	24.4	912	3.97	2.15	46.67
Lindera benzoin	22.1	1771	7.71	4.17	40.00
Rubus phoenicolasius	19.4	872	3.80	2.06	36.67
Viburnum dentatum	17.2	473	2.06	1.11	33.33
Rubus pensilvanicus	11.5	1262	5.49	2.97	20.00
Acer pseudoplatanus	8.9	472	2.06	1.11	16.67
Lonicera maackii	8.7	308	1.34	0.73	16.67
Rubus occidentalis	8.6	245	1.07	0.58	16.67
Acer platanoides	8.6	242	1.05	0.57	16.67
Celastrus orbiculatus	7.2	459	2.00	1.08	13.33
Vitis riparia	7.0	322	1.40	0.76	13.33
Hedera helix	6.5	1310	5.70	3.09	10.00
Sassafras albidum	5.5	393	1.71	0.93	10.00
Acer negundo	5.2	170	0.74	0.40	10.00
Acer saccharum	5.2	155	0.67	0.37	10.00
Rubus allegheniensis	4.0	553	2.41	1.30	6.67
Rubus flagellaris	3.6	201	0.88	0.47	6.67
Smilax rotundifolia	3.5	153	0.67	0.36	6.67
Liriodendron tulipifera	3.5	104	0.45	0.25	6.67
Frangula alnus	3.4	37	0.16	0.09	6.67
Pachysandra terminalis	3.4	32	0.14	0.08	6.67
Acer saccharinum	3.3	13	0.06	0.03	6.67
Prunus avium	2.0	259	1.13	0.61	3.33
Rhus typhina	1.8	138	0.60	0.33	3.33

Vinca minor	1.8	132	0.57	0.31	3.33
Ligustrum obtusifolium	1.8	128	0.56	0.30	3.33
Clethra alnifolia	1.8	100	0.44	0.24	3.33
Rubus odoratus	1.7	67	0.29	0.16	3.33
Viburnum prunifolium	1.7	55	0.24	0.13	3.33
Wisteria sinensis	1.7	52	0.23	0.12	3.33
Rubus laciniatus	1.7	30	0.13	0.07	3.33
Crataegus monogyna	1.7	6	0.03	0.01	3.33
Vitis x novae-angliae	1.7	4	0.02	0.01	3.33
Cornus florida	1.7	1	0.00	0.00	3.33
Acer rubrum		0			
Ailanthus altissima		0			
Clematis virginiana		0			
Cornus amomum		0			
Ilex crenata		0			
Ilex verticillata		0			
Liquidambar styraciflua		0			
Lonicera morrowii		0			
Rhodotypos scandens		0			
Robinia pseudoacacia		0			
Sambucus nigra		0			
Tilia americana		0			
Viburnum dilatatum		0			
Viburnum opulus		0			
Viburnum sieboldii		0			
Vitis aestivalis		0			
Vitis labrusca		0			
Unrestored					
Rosa multiflora	60.5	30408	29.12	24.40	96.67
Ampelopsis brevipedunculata	49.7	24214	23.19	19.43	80.00
Celastrus orbiculatus	44.0	9882	9.46	7.93	80.00
Lonicera japonica	45.1	8474	8.12	6.80	83.33
Rubus pensilvanicus	37.2	5406	5.18	4.34	70.00
Parthenocissus quinquefolia	48.6	4787	4.58	3.84	93.33
Toxicodendron radicans	38.4	4305	4.12	3.45	73.33
Vitis aestivalis	20.0	4038	3.87	3.24	36.67
Vitis labrusca	9.1	2020	1.93	1.62	16.67
Rubus phoenicolasius	15.8	1940	1.86	1.56	30.00
Vitis riparia	3.8	1260	1.21	1.01	6.67
Sassafras albidum	25.5	1190	1.14	0.95	50.00
Viburnum dentatum	20.4	1026	0.98	0.82	40.00
Prunus serotina	18.7	818	0.78	0.66	36.67
Lonicera morrowii	3.6	551	0.53	0.44	6.67
Smilax rotundifolia	10.2	503	0.48	0.40	20.00
Lonicera maackii	10.2	395	0.38	0.32	20.00
Lindera benzoin	8.5	371	0.36	0.30	16.67

Viburnum prunifolium	5.1	299	0.29	0.24	10.00
Rubus occidentalis	6.8	249	0.24	0.20	13.33
Rubus flagellaris	11.8	235	0.23	0.19	23.33
Wisteria sinensis	1.8	235	0.23	0.19	3.33
Viburnum dilatatum	1.8	228	0.22	0.18	3.33
Acer saccharum	1.7	195	0.19	0.16	3.33
Acer rubrum	3.4	188	0.18	0.15	6.67
Ligustrum obtusifolium	3.4	156	0.15	0.13	6.67
Rubus allegheniensis	5.1	137	0.13	0.11	10.00
Sambucus nigra	1.7	135	0.13	0.11	3.33
Ilex crenata	1.7	119	0.11	0.10	3.33
Rhodotypos scandens	3.4	95	0.09	0.08	6.67
Viburnum opulus	1.7	83	0.08	0.07	3.33
Cornus amomum	1.7	75	0.07	0.06	3.33
Robinia pseudoacacia	6.7	66	0.06	0.05	13.33
Liquidambar styraciflua	3.4	50	0.05	0.04	6.67
Tilia americana	1.7	50	0.05	0.04	3.33
Frangula alnus	3.4	46	0.04	0.04	6.67
Acer platanoides	3.3	41	0.04	0.03	6.67
Viburnum sieboldii	1.7	36	0.03	0.03	3.33
Hedera helix	3.3	27	0.03	0.02	6.67
Acer pseudoplatanus	1.7	25	0.02	0.02	3.33
Ailanthus altissima	3.3	16	0.02	0.01	6.67
Cornus florida	1.7	15	0.01	0.01	3.33
Ilex verticillata	1.7	12	0.01	0.01	3.33
Clematis virginiana	1.7	8	0.01	0.01	3.33
Acer negundo		0			
Acer saccharinum		0			
Clethra alnifolia		0			
Crataegus monogyna		0			
Liriodendron tulipifera		0			
Pachysandra terminalis		0			
Prunus avium		0			
Rhus typhina		0			
Rubus laciniatus		0			
Rubus odoratus		0			
Vinca minor		0			
Vitis x novae-angliae		0			

A.3.3.5. Lifespan of Tree Species in the Ground Layer

A.43. Tree species with long lifespans in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by tree species with long lifespans in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Long Lifespan Cover**	**% Total Cover**	**% of Plots**
Restored					
Acer saccharum	5.18	155	72.43	0.37	10.00
Quercus rubra	5.09	75	35.05	0.18	10.00
Quercus alba	3.40	59	27.57	0.14	6.67
Liquidambar styraciflua		0			
Unrestored					
Acer saccharum	1.74	195	79.59	0.156	3.33
Liquidambar styraciflua	3.35	50	20.41	0.040	6.67
Quercus rubra	5.02	43	17.55	0.035	10.00
Quercus alba		0			

A.44. Tree species with moderate lifespans in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by tree species with moderate lifespans in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Moderate Lifespan Cover	% Total Cover	% of Plots
Restored					
Prunus serotina	28.7	349	23.79	0.823	56.67
Carya cordiformis	18.9	450	30.67	1.06	36.67
Acer pseudoplatanus	8.9	472	32.17	1.11	16.67
Liriodendron tulipifera	3.5	104	7.09	0.25	6.67
Celtis occidentalis	3.4	19	1.30	0.04	6.67
Populus alba	1.8	73	4.98	0.172	3.33
Fraxinus americana	0.0	0			
Juglans nigra	0.0	0			
Morus alba	0.0	0			
Quercus palustris	0.0	0			
Quercus velutina	0.0	0			
Tilia americana	0.0	0			
Unrestored					
Prunus serotina	18.7	818	53.71	0.66	36.67
Carya cordiformis	11.7	157	10.31	0.13	23.33
Morus alba	6.8	211	13.85	0.17	13.33
Juglans nigra	5.0	109	7.16	0.087	10.00
Quercus velutina	5.0	47	3.09	0.04	10.00
Fraxinus americana	3.4	75	4.92	0.060	6.67
Tilia americana	1.7	50	3.28	0.040	3.33
Quercus palustris	1.7	31	2.04	0.02	3.33
Acer pseudoplatanus	1.7	25	1.64	0.02	3.33
Celtis occidentalis	0.0	0			
Liriodendron tulipifera	0.0	0			
Populus alba	0.0	0			

A.45. Tree species with short lifespans in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by tree species with short lifespans in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Short Lifespan Cover	% Total Cover	% of Plots
Restored					
Fraxinus pennsylvanica	14.3	829	43.47	1.95	26.67
Acer platanoides	8.6	242	12.69	0.57	16.67
Sassafras albidum	5.5	393	20.61	0.93	10.00
Acer negundo	5.2	170	8.91	0.40	10.00
Acer saccharinum	3.3	13	0.68	0.031	6.67
Prunus avium	2.0	259	13.58	0.61	3.33
Cornus florida	1.7	1	0.05	0.00	3.33
Acer rubrum	0.0	0			
Ailanthus altissima	0.0	0			
Robinia pseudoacacia	0.0	0			
Unrestored					
Sassafras albidum	25.5	1190	77.88	0.95	50.00
Robinia pseudoacacia	6.7	66	4.32	0.053	13.33
Acer rubrum	3.4	188	12.30	0.151	6.67
Acer platanoides	3.3	41	2.68	0.033	6.67
Ailanthus altissima	3.3	16	1.05	0.01	6.67
Cornus florida	1.7	15	0.98	0.012	3.33
Fraxinus pennsylvanica	1.7	12	0.79	0.01	3.33
Acer negundo	0.0	0			
Acer saccharinum	0.0	0			
Prunus avium	0.0	0			

A.3.4 Herbaceous Species in the Ground Layer

A.3.4.1 Growth Forms of Herbaceous Species in the Ground Layer

A.46. Annual species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by annual species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Annual Cover	% Total Cover	% of Plots
Restored					
Impatiens capensis	23.3	2758	89.0	6.50	40.00
Amphicarpaea bracteata	3.6	217	7.0	0.51	6.67
Polygonum cespitosum	3.4	20	0.6	0.05	6.67
Echinocystis lobata	1.7	47	1.5	0.11	3.33
Sicyos angulatus	1.7	33	1.1	0.08	3.33
Ambrosia trifida	1.7	22	0.7	0.05	3.33
Pilea pumila	1.7	1	0.0	0.00	3.33
Humulus japonicus		0			
Polygonum perfoliatum		0			
Unrestored					
Impatiens capensis	31.8	4492	89.1	3.60	60.00
Polygonum cespitosum	5.0	69	1.4	0.06	10.00
Polygonum perfoliatum	1.8	402	8.0	0.32	3.33
Pilea pumila	1.7	50	1.0	0.04	3.33
Humulus japonicus	1.7	20	0.4	0.02	3.33
Sicyos angulatus	1.7	7	0.1	0.01	3.33
Ambrosia trifida		0			
Amphicarpaea bracteata		0			
Echinocystis lobata		0			

A.47. Perennial species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by perennial species in the ground layer, percent of total cover in restored and unrestored plotsplots, and percent of plots where species were sampled. Species are ranked by their IVI.

Restored **Species**	**IVI**	**Cover (cm)**	**% Perennial Cover**	**% Total Cover**	**% of Plots**
Circaea lutetiana	48.5	4395	35.5	10.36	86.67
Phytolacca americana	14.3	809	6.5	1.91	26.67
Hemerocallis fulva	13.0	1097	8.9	2.59	23.33
Geum canadense	12.4	610	4.9	1.44	23.33
Ageratina altissima	12.2	479	3.9	1.13	23.33
Eurybia divaricata	10.5	420	3.4	0.99	20.00
Polygonum persicaria	10.3	292	2.4	0.69	20.00
Solidago caesia	10.1	75	0.6	0.18	20.00
Aegopodium podagraria	7.9	2499	20.2	5.89	10.00
Viola sororia	5.1	81	0.7	0.19	10.00
Solanum dulcamara	5.1	61	0.5	0.14	10.00
Polygonum virginianum	3.9	470	3.8	1.11	6.67
Duchesnea indica	3.8	363	2.9	0.86	6.67
Maianthemum racemosum	3.4	86	0.7	0.20	6.67
Oxalis stricta	3.4	29	0.2	0.07	6.67
Sanicula canadensis	3.4	16	0.1	0.04	6.67
Laportea canadensis	2.0	289	2.3	0.68	3.33
Hesperis matronalis	1.8	115	0.9	0.27	3.33
Polygonatum biflorum	1.7	65	0.5	0.15	3.33
Arctium minus	1.7	47	0.4	0.11	3.33
Geranium maculatum	1.7	28	0.2	0.07	3.33
Narcissus pseudonarcissus	1.7	23	0.2	0.05	3.33
Artemisia vulgaris	1.7	10	0.1	0.02	3.33
Scrophularia marilandica	1.7	10	0.1	0.02	3.33
Symphyotrichum cordifolium	1.7	9	0.1	0.02	3.33

Epipactis helleborine	1.7	5	0.04	0.01	3.33
Arisaema triphyllum		0			
Barbarea vulgaris		0			
Convallaria majalis		0			
Epilobium ciliatum		0			
Eutrochium purpureum		0			
Humulus lupulus		0			
Lysimachia ciliata		0			
Oxalis dillenii		0			
Polygonum sagittatum		0			
Smilax herbacea		0			
Taraxacum officinale		0			
Unrestored					
Circaea lutetiana	32.4	1775	25.6	1.42	63.33
Geum canadense	21.9	584	8.4	0.47	43.33
Maianthemum racemosum	11.8	397	5.7	0.32	23.33
Artemisia vulgaris	7.8	2819	40.7	2.26	13.33
Polygonatum biflorum	6.7	70	1.0	0.06	13.33
Eurybia divaricata	5.1	278	4.0	0.22	10.00
Phytolacca americana	5.0	65	0.9	0.05	10.00
Solanum dulcamara	5.0	60	0.9	0.05	10.00
Duchesnea indica	3.4	114	1.6	0.09	6.67
Lysimachia ciliata	3.4	100	1.4	0.08	6.67
Oxalis stricta	3.3	30	0.4	0.02	6.67
Smilax herbacea	3.3	9	0.1	0.01	6.67
Arisaema triphyllum	3.3	6	0.1	0.005	6.67
Barbarea vulgaris	1.7	134	1.9	0.11	3.33
Polygonum persicaria	1.7	130	1.9	0.10	3.33
Epilobium ciliatum	1.7	98	1.4	0.08	3.33
Ageratina altissima	1.7	56	0.8	0.04	3.33
Eutrochium purpureum	1.7	56	0.8	0.04	3.33
Polygonum sagittatum	1.7	48	0.7	0.04	3.33
Oxalis dillenii	1.7	39	0.6	0.03	3.33
Humulus lupulus	1.7	25	0.4	0.02	3.33
Taraxacum officinale	1.7	17	0.2	0.01	3.33
Convallaria majalis	1.7	16	0.2	0.01	3.33
Polygonum virginianum	1.7	5	0.1	0.004	3.33
Viola sororia	1.7	3	0.0	0.002	3.33
Aegopodium podagraria		0			

Arctium minus	0
Epipactis helleborine	0
Geranium maculatum	0
Hemerocallis fulva	0
Hesperis matronalis	0
Laportea canadensis	0
Narcissus pseudonarcissus	0
Sanicula canadensis	0
Scrophularia marilandica	0
Solidago caesia	0
Symphyotrichum cordifolium	0

A.48. Biennial species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by biennial species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Cover (cm)**	**% Biennial cover**	**% Total Cover**	**% of Plots**
Alliaria petiolata	39.2	2167	100.0	5.1	73.3
Lactuca biennis		0	0.0	0.0	0.0
Unrestored					
Alliaria petiolata	45.7	5995	99.6	4.8	86.7
Lactuca biennis	1.7	27	0.4	0.0	3.3

A.49. Fern species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by fern species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Fern cover	% Total Cover	% of Plots
Restored					
Onoclea sensibilis	1.7	49	51.04	0.12	3.33
Pteris multifida	1.7	47	48.96	0.11	3.33
Thelypteris noveboracensis		0			
Unrestored					
Onoclea sensibilis	3.4	138	83.13	0.11	6.67
Thelypteris noveboracensis	1.7	28	16.87	0.02	3.33
Pteris multifida		0			

A.50. Parasite species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

	Species	IVI	Cover (cm)	% Total Cover	% of Plots
Restored	***Cuscuta gronovii***		0		
Unrestored	***Cuscuta gronovii***	1.8	99	0.23	3.33

A.51. Graminoid species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by graminoid species in the ground layer, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Restored					
Species	**IVI**	**Cover (cm)**	**% Graminoid cover**	**% Total Cover**	**% of Plots**
Carex annectens		0	0	0	0
Carex vulpinoidea		0	0	0	0
Juncus tenuis		0	0	0	0
Phragmites australis		0	0	0	0
Poa trivialis		0	0	0	0
Unrestored					
Carex vulpinoidea	1.7	99	38.7	0.08	3.3
Phragmites australis	1.7	75	29.3	0.06	3.3
Carex annectens	1.7	33	12.9	0.03	3.3
Juncus tenuis	1.7	32	12.5	0.03	3.3
Poa trivialis	1.7	17	6.6	0.01	3.3

A.3.4.2 Shade Tolerance of Herbaceous Species in the Ground Layer

A.52. Shade tolerant herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by shade tolerant herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Shade Tolerant Cover	%Total Cover	% of Plots
Restored					
Alliaria petiolata	39.2	2167	31.10	5.11	73.33
Impatiens capensis	23.3	2758	39.58	6.50	40.00
Phytolacca americana	14.3	809	11.61	1.91	26.67
Geum canadense	12.4	610	8.75	1.44	23.33
Eurybia divaricata	10.5	420	6.03	0.99	20.00
Solanum dulcamara	5.1	61	0.88	0.14	10.00
Polygonum virginianum	3.9	470	5.04	1.11	6.67
Maianthemum racemosum	3.4	86	0.92	0.20	6.67
Polygonatum biflorum	1.7	65	0.93	0.15	3.33
Onoclea sensibilis	1.7	49	0.70	0.12	3.33
Pilea pumila	1.7	1	0.01	0.00	3.33
Arisaema triphyllum		0			
Convallaria majalis		0			
Dennstaedtia punctilobula		0			
Lysimachia ciliata		0			
Poa trivialis		0			
Polygonum perfoliatum		0			
Thelypteris noveboracensis		0			
Unrestored					
Alliaria petiolata	45.7	5995	49.95	4.81	86.67
Impatiens capensis	31.8	4492	37.42	3.60	60.00
Geum canadense	21.9	584	4.87	0.47	43.33
Maianthemum racemosum	11.8	397	13.52	0.32	23.33
Polygonatum biflorum	6.7	70	0.58	0.06	13.33

Eurybia divaricata	5.1	278	2.32	0.22	10.00
Phytolacca americana	5.0	65	0.54	0.05	10.00
Solanum dulcamara	5.0	60	0.50	0.05	10.00
Onoclea sensibilis	3.4	138	1.15	0.11	6.67
Lysimachia ciliata	3.4	100	0.83	0.08	6.67
Arisaema triphyllum	3.3	6	0.05	0.00	6.67
Polygonum perfoliatum	1.8	402	13.69	0.32	3.33
Dennstaedtia punctilobula	1.7	104	0.87	0.08	3.33
Pilea pumila	1.7	50	0.42	0.04	3.33
Polygonum virginianum	1.7	5	0.17	0.00	3.33
Thelypteris noveboracensis	1.7	28	0.23	0.02	3.33
Poa trivialis	1.7	17	0.14	0.01	3.33
Convallaria majalis	1.7	16	0.13	0.01	3.33

A.53. Intermediate shade tolerant herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by intermediate shade tolerant herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	**IVI**	**Cover (cm)**	**% Intermediate Shade Tolerant Cover**	**%Total Cover**	**% of Plots**
Restored					
Circaea lutetiana	48.5	4395	47.11	10.36	86.67
Hemerocallis fulva	13.0	1097	11.76	2.59	23.33
Ageratina altissima	12.2	479	5.13	1.13	23.33
Solidago caesia	10.1	75	0.80	0.18	20.00
Aegopodium podagraria	7.9	2499	26.78	5.89	10.00
Viola sororia	5.1	81	0.87	0.19	10.00
Hesperis matronalis	1.8	115	1.23	0.27	3.33
Artemisia vulgaris	1.7	10	2.58	0.02	3.33
Geranium maculatum	1.7	28	0.40	0.07	3.33
Narcissus pseudonarcissus	1.7	23	0.25	0.05	3.33
Scrophularia marilandica	1.7	10	0.11	0.02	3.33
Carex annectens		0			
Carex vulpinoidea		0			
Eutrochium purpureum		0			
Humulus lupulus		0			
Juncus tenuis		0			
Lactuca biennis		0			
Smilax herbacea		0			
Taraxacum officinale		0			
Unrestored					
Circaea lutetiana	32.4	1775	60.46	1.42	63.33
Artemisia vulgaris	7.8	2819	90.29	2.26	13.33
Smilax herbacea	3.3	9	0.31	0.01	6.67
Carex vulpinoidea	1.7	99	3.37	0.08	3.33

Ageratina altissima	1.7	56	1.91	0.04	3.33
Eutrochium purpureum	1.7	56	1.91	0.04	3.33
Carex annectens	1.7	33	1.12	0.03	3.33
Juncus tenuis	1.7	32	1.09	0.03	3.33
Lactuca biennis	1.7	27	0.92	0.02	3.33
Humulus lupulus	1.7	25	0.85	0.02	3.33
Taraxacum officinale	1.7	17	0.58	0.01	3.33
Viola sororia	1.7	3	0.10	0.002	3.33
Aegopodium podagraria		0			
Geranium maculatum		0			
Hemerocallis fulva		0			
Hesperis matronalis		0			
Narcissus pseudonarcissus		0			
Scrophularia marilandica		0			
Solidago caesia		0			

A.54. Shade intolerant herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by shade intolerant herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Shade Intolerant Cover	%Total Cover	% of Plots
Restored					
Polygonum persicaria	10.3	292	75.45	0.69	20.00
Oxalis stricta	3.4	29	7.49	0.07	6.67
Echinocystis lobata	1.7	47	12.14	0.11	3.33
Symphyotrichum cordifolium	1.7	9	2.33	0.02	3.33
Humulus japonicus		0			
Phragmites australis		0			
Polygonum sagittatum		0			
Unrestored					
Oxalis stricta	3.3	30	0.96	0.02	6.67
Polygonum persicaria	1.7	130	4.16	0.10	3.33
Phragmites australis	1.7	75	2.40	0.06	3.33
Polygonum sagittatum	1.7	48	1.54	0.04	3.33
Humulus japonicus	1.7	20	0.64	0.02	3.33
Echinocystis lobata		0			
Symphyotrichum cordifolium		0			

A.3.4.3 Seed Dispersal of Herbaceous Species in the Ground Layer

A.55. Herbaceous species with unassisted seed dispersal in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by herbaceous species with unassisted seed dispersal, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	Cover (cm)	IVI	% Unassisted Dispersal Cover	% Total Cover	% of Plots
Restored					
Alliaria petiolata	2167	39.2	30.74	5.11	73.33
Hemerocallis fulva	1097	13.0	15.56	2.59	23.33
Polygonum persicaria	292	10.3	4.14	0.69	20.00
Aegopodium podagraria	2499	7.9	35.45	5.89	10.00
Polygonum virginianum	470	3.9	6.67	1.11	6.67
Polygonum cespitosum	20	3.4	0.28	0.05	6.67
Laportea canadensis	289	2.0	4.10	0.68	3.33
Hesperis matronalis	115	1.8	1.63	0.27	3.33
Echinocystis lobata	47	1.7	0.67	0.11	3.33
Sicyos angulatus	33	1.7	0.47	0.08	3.33
Artemisia vulgaris	10	1.7	0.14	0.02	3.33
Scrophularia marilandica	10	1.7	0.14	0.02	3.33
Pilea pumila	1	1.7	0.01	0.002	3.33
Barbarea vulgaris	0				
Cuscuta gronovii	0				
Lysimachia ciliata	0				
Polygonum sagittatum	0				
Unrestored					
Alliaria petiolata	5995	45.7	63.40	4.81	86.67
Artemisia vulgaris	2819	7.8	29.81	2.26	13.33
Polygonum cespitosum	69	5.0	0.73	0.06	10.00
Lysimachia ciliata	100	3.4	1.06	0.08	6.67
Barbarea vulgaris	134	1.7	1.42	0.11	3.33

Polygonum persicaria	130	1.7	1.37	0.10	3.33
Cuscuta gronovii	99	1.7	1.05	0.08	3.33
Pilea pumila	50	1.7	0.53	0.04	3.33
Polygonum sagittatum	48	1.7	0.51	0.04	3.33
Sicyos angulatus	7	1.7	0.07	0.01	3.33
Polygonum virginianum	5	1.7	0.05	0.004	3.33
Aegopodium podagraria	0				
Echinocystis lobata	0				
Hemerocallis fulva	0				
Hesperis matronalis	0				
Laportea canadensis	0				
Scrophularia marilandica	0				

A.56. Wind dispersed herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by herbaceous species with wind dispersal, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	Cover (cm)	IVI	% Wind Dispersal Cover	% Total Cover	% of Plots
Restored					
Geum canadense	610	12.4	36.53	1.44	23.33
Ageratina altissima	479	12.2	28.68	1.13	23.33
Eurybia divaricata	420	10.5	25.15	0.99	20.00
Solidago caesia	75	10.1	4.49	0.18	20.00
Onoclea sensibilis	49	1.7	2.93	0.12	3.33
Narcissus pseudonarcissus	23	1.7	1.38	0.05	3.33
Symphyotrichum cordifolium	9	1.7	0.54	0.02	3.33
Epipactis helleborine	5	1.7	0.30	0.01	3.33
Carex annectens	0				
Carex vulpinoidea	0				
Dennstaedtia punctilobula	0				
Epilobium ciliatum	0				
Humulus japonicus	0				
Humulus lupulus	0				
Lactuca biennis	0				
Poa trivialis	0				
Taraxacum officinale	0				
Thelypteris noveboracensis	0				
Unrestored					
Geum canadense	584	21.9	0.95	0.47	43.33
Eurybia divaricata	278	5.1	0.45	0.22	10.00
Onoclea sensibilis	138	3.4	0.22	0.11	6.67
Dennstaedtia punctilobula	104	1.7	0.17	0.08	3.33
Carex vulpinoidea	99	1.7	0.16	0.08	3.33
Epilobium ciliatum	98	1.7	0.16	0.08	3.33

Ageratina altissima	56	1.7	0.09	0.04	3.33
Carex annectens	33	1.7	0.05	0.03	3.33
Thelypteris noveboracensis	28	1.7	0.05	0.02	3.33
Lactuca biennis	27	1.7	0.04	0.02	3.33
Humulus lupulus	25	1.7	0.04	0.02	3.33
Humulus japonicus	20	1.7	0.03	0.02	3.33
Poa trivialis	17	1.7	0.03	0.01	3.33
Taraxacum officinale	17	1.7	0.03	0.01	3.33
Epipactis helleborine	0				
Narcissus pseudonarcissus	0				
Solidago caesia	0				
Symphyotrichum cordifolium	0				

A.57. Endozoochoric herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by endozoochoric herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Endozoochory Cover	% Total Cover	% of Plots
Restored					
Phytolacca americana	14.3	809	79.24	1.91	26.67
Solanum dulcamara	5.1	61	5.97	0.14	10.00
Maianthemum racemosum	3.4	86	8.42	0.20	6.67
Polygonatum biflorum	1.7	65	6.37	0.15	3.33
Arisaema triphyllum		0			
Convallaria majalis		0			
Polygonum perfoliatum		0			
Smilax herbacea		0			
Unrestored					
Maianthemum racemosum	11.8	397	38.73	0.32	23.33
Polygonatum biflorum	6.7	70	6.83	0.06	13.33
Phytolacca americana	5.0	65	6.34	0.05	10.00
Solanum dulcamara	5.0	60	5.85	0.05	10.00
Smilax herbacea	3.3	9	0.88	0.01	6.67
Arisaema triphyllum	3.3	6	0.59	0.00	6.67
Polygonum perfoliatum	1.8	402	39.22	0.32	3.33
Convallaria majalis	1.7	16	1.56	0.01	3.33

A.58. Exozoochoric herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by exozoochoric herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Exozoochory Cover	% Total Cover	% of Plots
Restored					
Circaea lutetiana	48.5	4395	90.75	10.36	86.67
Duchesnea indica	3.8	363	7.50	0.86	6.67
Sanicula canadensis	3.4	16	0.33	0.04	6.67
Arctium minus	1.7	47	0.97	0.11	3.33
Ambrosia trifida	1.7	22	0.45	0.05	3.33
Juncus tenuis		0			
Phragmites australis		0			
Unrestored					
Circaea lutetiana	32.4	1775	88.93	1.42	63.33
Duchesnea indica	3.4	114	5.71	0.09	6.67
Phragmites australis	1.7	75	3.76	0.06	3.33
Juncus tenuis	1.7	32	1.60	0.03	3.33
Ambrosia trifida		0			
Arctium minus		0			
Sanicula canadensis		0			

A.59. Herbaceous species with other dispersal methods in the ground layer of restored (n=30) and unrestored plots (n=30). Other dispersal methods were water dispersal and dispersal by launching. Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by herbaceous species with other dispersal modes, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Other Dispersal Cover	% Total Cover	% of Plots
Restored					
Impatiens capensis	23.3	2758	88.60	6.50	40.00
Viola sororia	5.1	81	2.60	0.19	10.00
Amphicarpaea bracteata	3.6	217	6.97	0.51	6.67
Oxalis stricta	3.4	29	0.93	0.07	6.67
Geranium maculatum	1.7	28	0.90	0.07	3.33
Oxalis dillenii		0			
Unrestored					
Impatiens capensis	31.8	4492	98.42	3.60	60.00
Oxalis stricta	3.3	30	0.66	0.02	6.67
Oxalis dillenii	1.7	39	0.85	0.03	3.33
Viola sororia	1.7	3	0.07	0.002	3.33
Geranium maculatum		0			
Amphicarpaea bracteata		0			

A.3.4.4 Pollination Syndromes of Herbaceous Species in the Ground Layer

A. 60. Abiotically pollinated herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by abiotically pollinated herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

Species	IVI	Cover (cm)	% Abiotic Pollination Cover	% Total Cover	% of Plots
Restored					
Laportea canadensis	2.0	289	77.90	0.68	3.33
Onoclea sensibilis	1.7	49	13.21	0.12	3.33
Ambrosia trifida	1.7	22	5.93	0.05	3.33
Artemisia vulgaris	1.7	10	2.70	0.02	3.33
Pilea pumila	1.7	1	0.27	0.00	3.33
Carex annectens		0			
Carex vulpinoidea		0			
Dennstaedtia punctilobula		0			
Juncus tenuis		0			
Poa trivialis		0			
Thelypteris noveboracensis		0			
Unrestored					
Artemisia vulgaris	7.8	2819	84.91	2.26	13.33
Onoclea sensibilis	3.4	138	4.16	0.11	6.67
Dennstaedtia punctilobula	1.7	104	3.13	0.08	3.33
Carex vulpinoidea	1.7	99	2.98	0.08	3.33
Pilea pumila	1.7	50	1.51	0.04	3.33
Carex annectens	1.7	33	0.99	0.03	3.33
Juncus tenuis	1.7	32	0.96	0.03	3.33
Thelypteris noveboracensis	1.7	28	0.84	0.02	3.33
Poa trivialis	1.7	17	0.51	0.01	3.33
Ambrosia trifida		0			
Laportea canadensis		0			

A.61. Biotically pollinated herbaceous species in the ground layer of restored (n=30) and unrestored plots (n=30). Species information includes: importance value index (IVI) (Williams-Linera, Palacios-Rios, and Hernández-Gómez 2005), total cover, percent of cover by biotically pollinated herbaceous species, percent of total cover in restored and unrestored plots, and percent of restored and unrestored plots where species were sampled. Species are ranked by their IVI.

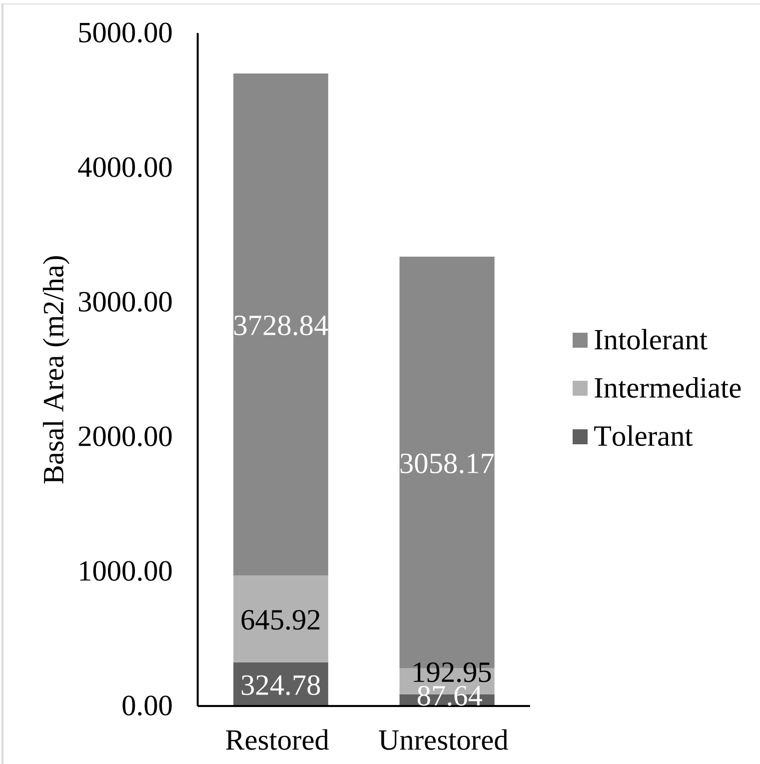
Restored					
Species	**IVI**	**Cover (cm)**	**% Biotic Pollination Cover**	**% Total Cover**	**% of Plots**
Circaea lutetiana	48.5	4395	25.37	10.36	86.67
Alliaria petiolata	39.2	2167	12.51	5.11	73.33
Impatiens capensis	23.3	2758	15.92	6.50	40.00
Phytolacca americana	14.3	809	4.67	1.91	26.67
Hemerocallis fulva	13.0	1097	6.33	2.59	23.33
Geum canadense	12.4	610	3.52	1.44	23.33
Ageratina altissima	12.2	479	2.76	1.13	23.33
Eurybia divaricata	10.5	420	2.42	0.99	20.00
Polygonum persicaria	10.3	292	1.69	0.69	20.00
Solidago caesia	10.1	75	0.43	0.18	20.00
Aegopodium podagraria	7.9	2499	14.42	5.89	10.00
Viola sororia	5.1	81	0.47	0.19	10.00
Solanum dulcamara	5.1	61	0.35	0.14	10.00
Polygonum virginianum	3.9	470	2.71	1.11	6.67
Duchesnea indica	3.8	363	2.10	0.86	6.67
Amphicarpaea bracteata	3.6	217	1.25	0.51	6.67
Maianthemum racemosum	3.4	86	0.50	0.20	6.67
Oxalis stricta	3.4	29	0.17	0.07	6.67
Polygonum cespitosum	3.4	20	0.12	0.05	6.67
Sanicula canadensis	3.4	16	0.09	0.04	6.67
Hesperis matronalis	1.8	115	0.66	0.27	3.33
Polygonatum biflorum	1.7	65	0.38	0.15	3.33
Arctium minus	1.7	47	0.27	0.11	3.33
Echinocystis lobata	1.7	47	0.27	0.11	3.33
Sicyos angulatus	1.7	33	0.19	0.08	3.33
Geranium maculatum	1.7	28	0.16	0.07	3.33
Narcissus pseudonarcissus	1.7	23	0.13	0.05	3.33
Scrophularia marilandica	1.7	10	0.06	0.02	3.33
Symphyotrichum cordifolium	1.7	9	0.05	0.02	3.33

Epipactis helleborine	1.7	5	0.03	0.01	3.33
Arisaema triphyllum		0			
Barbarea vulgaris		0			
Convallaria majalis		0			
Cuscuta gronovii		0			
Epilobium ciliatum		0			
Eutrochium purpureum		0			
Humulus japonicus		0			
Humulus lupulus		0			
Lactuca biennis		0			
Lysimachia ciliata		0			
Oxalis dillenii		0			
Phragmites australis		0			
Polygonum perfoliatum		0			
Polygonum sagittatum		0			
Smilax herbacea		0			
Taraxacum officinale		0			
Unrestored					
Alliaria petiolata	45.7	5995	39.18	4.81	86.67
Circaea lutetiana	32.4	1775	11.60	1.42	63.33
Impatiens capensis	31.8	4492	29.36	3.60	60.00
Geum canadense	21.9	584	3.82	0.47	43.33
Maianthemum racemosum	11.8	397	2.59	0.32	23.33
Polygonatum biflorum	6.7	70	0.46	0.06	13.33
Eurybia divaricata	5.1	278	1.82	0.22	10.00
Polygonum cespitosum	5.0	69	0.45	0.06	10.00
Phytolacca americana	5.0	65	0.42	0.05	10.00
Solanum dulcamara	5.0	60	0.39	0.05	10.00
Duchesnea indica	3.4	114	0.75	0.09	6.67
Lysimachia ciliata	3.4	100	0.65	0.08	6.67
Oxalis stricta	3.3	30	0.20	0.02	6.67
Smilax herbacea	3.3	9	0.06	0.01	6.67
Arisaema triphyllum	3.3	6	0.04	0.00	6.67
Polygonum perfoliatum	1.8	402	2.63	0.32	3.33
Barbarea vulgaris	1.7	134	0.88	0.11	3.33
Polygonum persicaria	1.7	130	0.85	0.10	3.33
Cuscuta gronovii	1.7	99	0.65	0.08	3.33
Epilobium ciliatum	1.7	98	0.64	0.08	3.33
Phragmites australis	1.7	75	0.49	0.06	3.33
Ageratina altissima	1.7	56	0.37	0.04	3.33
Eutrochium purpureum	1.7	56	0.37	0.04	3.33
Polygonum sagittatum	1.7	48	0.31	0.04	3.33
Oxalis dillenii	1.7	39	0.25	0.03	3.33
Lactuca biennis	1.7	27	0.18	0.02	3.33
Humulus lupulus	1.7	25	0.16	0.02	3.33

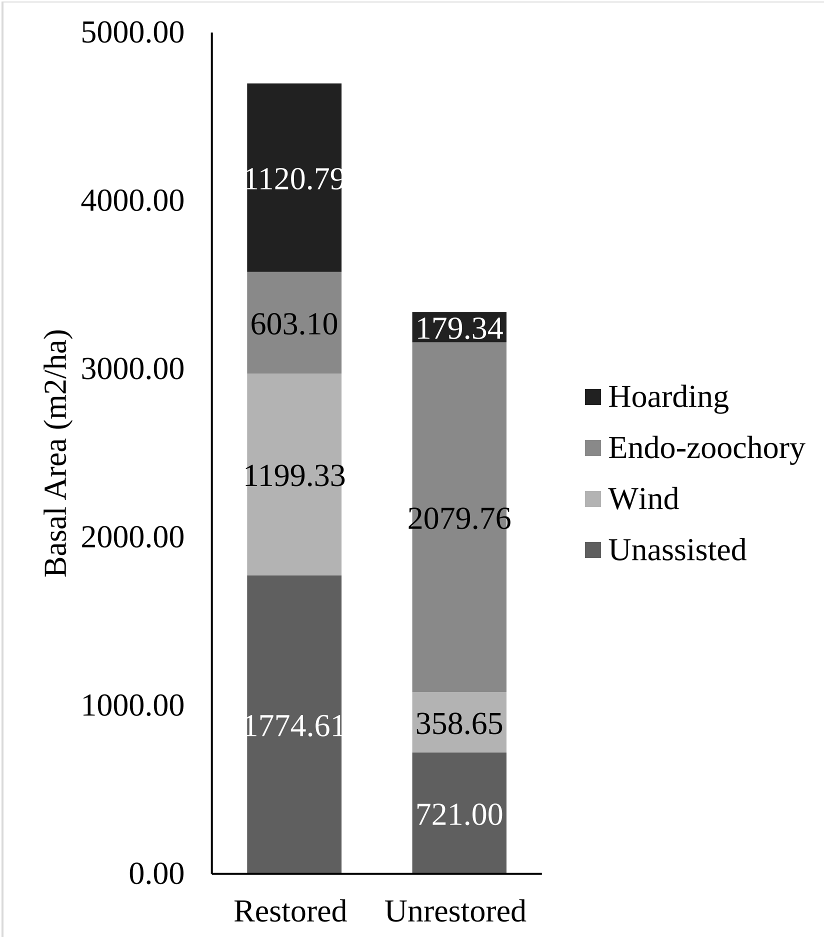
Humulus japonicus	1.7	20	0.13	0.02	3.33
Taraxacum officinale	1.7	17	0.11	0.01	3.33
Convallaria majalis	1.7	16	0.10	0.01	3.33
Sicyos angulatus	1.7	7	0.05	0.01	3.33
Polygonum virginianum	1.7	5	0.03	0.00	3.33
Viola sororia	1.7	3	0.02	0.00	3.33
Aegopodium podagraria		0			
Amphicarpaea bracteata		0			
Arctium minus		0			
Echinocystis lobata		0			
Epipactis helleborine		0			
Geranium maculatum		0			
Hemerocallis fulva		0			
Hesperis matronalis		0			
Narcissus pseudonarcissus		0			
Sanicula canadensis		0			
Scrophularia marilandica		0			
Solidago caesia		0			
Symphyotrichum cordifolium		0			

A.4 Functional Trait Composition by Total Species Abundance

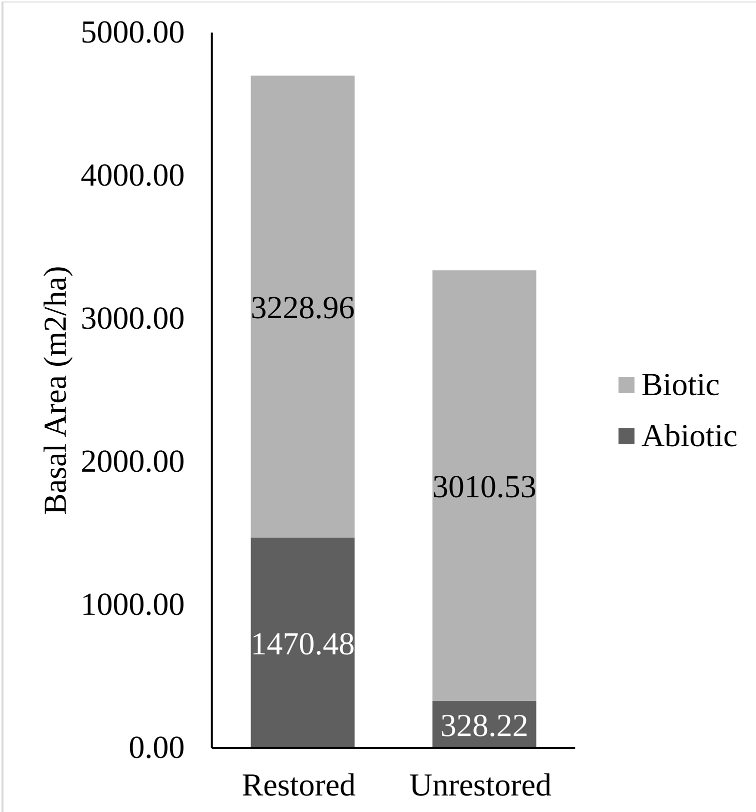
A.4.1 Functional Trait Composition by Tree Abundance



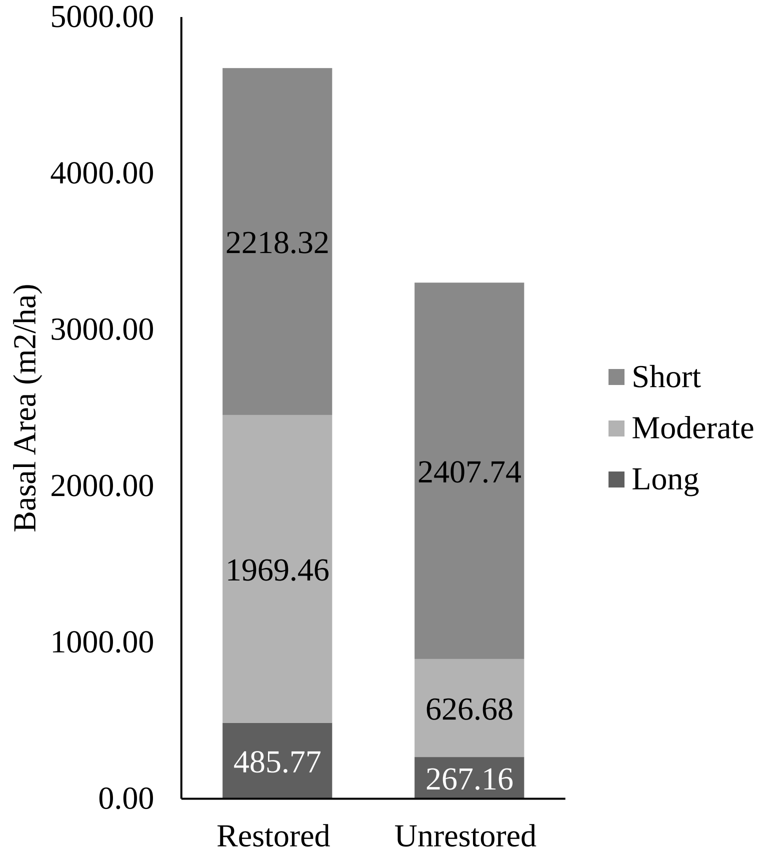
Appendix Figure 1. Tree basal area by shade tolerance level. Trees consisted of individuals of tree species with a DBH of > 2.54 cm and height of > 1 m. Restored (n=30) plots had a greater total basal area of trees.



Appendix Figure 2. Tree basal area by seed dispersal mode. Trees consisted of individuals of tree species with a DBH of > 2.54 cm and height of > 1 m. Restored (n=30) plots had a greater total basal area of trees.

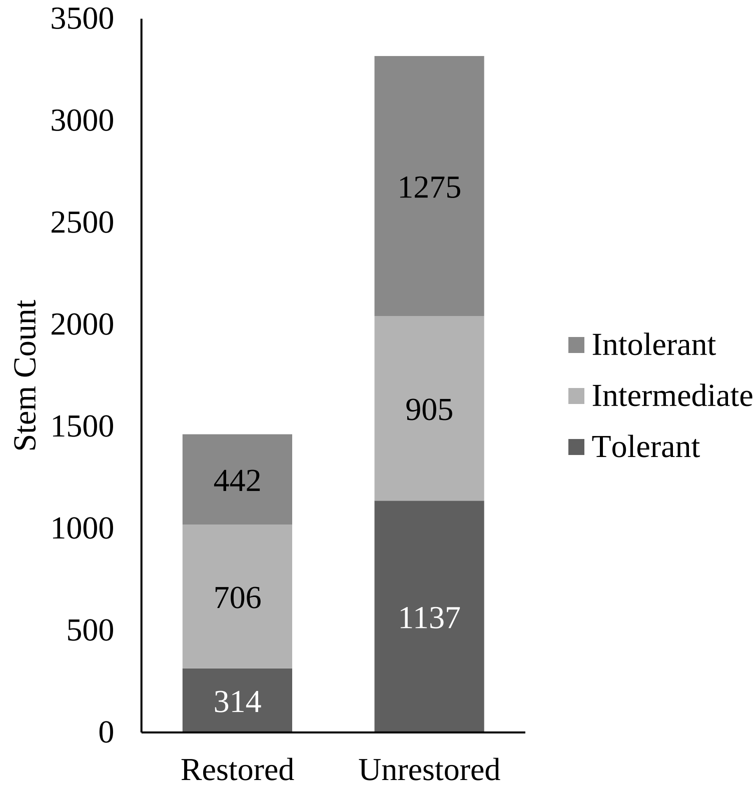


Appendix Figure 3. Tree basal area by pollination syndrome. Trees consisted of individuals of tree species with a DBH of > 2.54 cm and height of > 1 m. Restored (n=30) plots had a greater total basal area of trees.

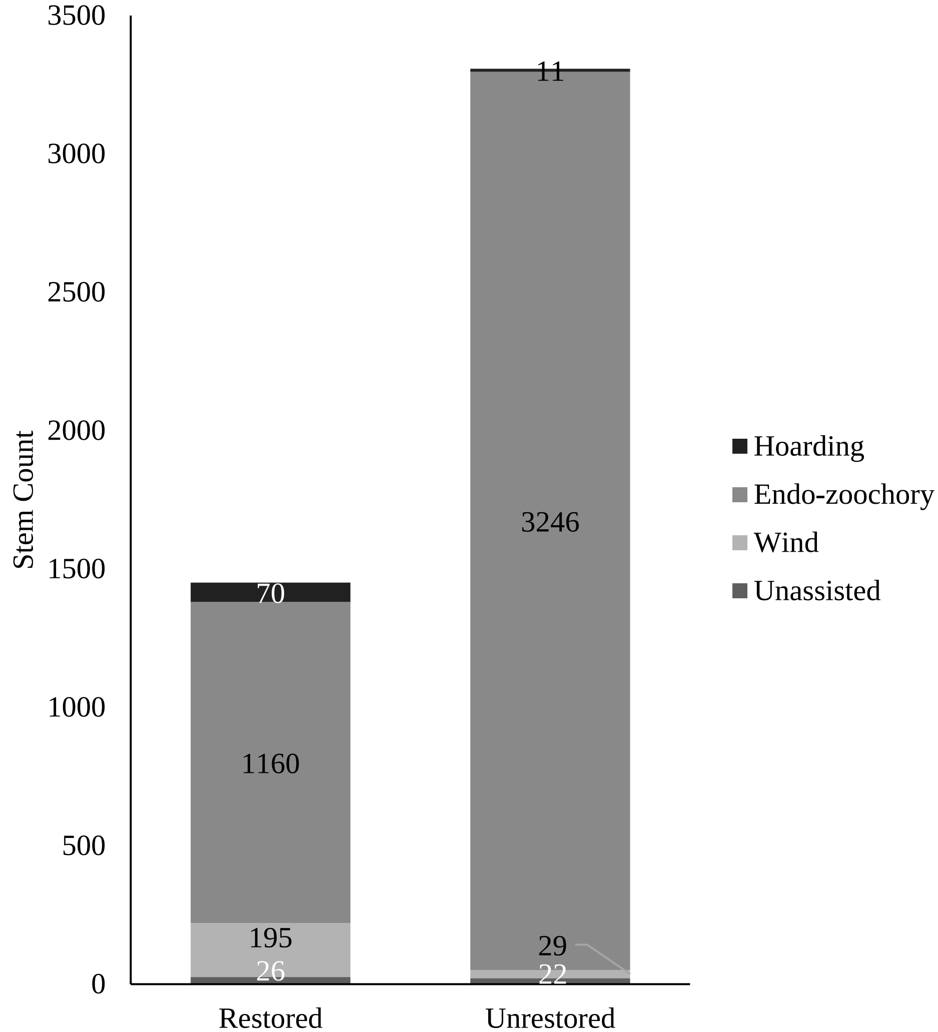


Appendix Figure 4. Tree basal area by tree lifespan. Trees consisted of individuals of tree species with a DBH of > 2.54 cm and height of > 1 m. Restored (n=30) plots had a greater total basal area of trees.

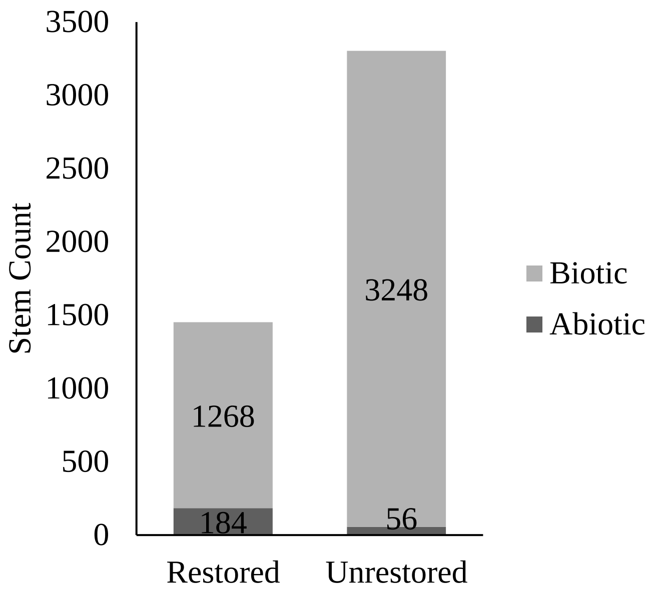
A.4.2 Functional Trait Composition by Abundance of Woody Understory Species



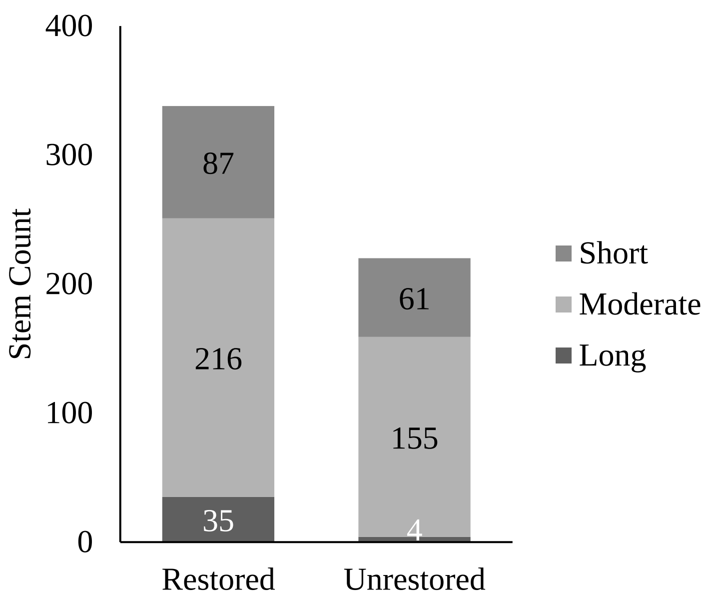
Appendix Figure 5. Woody understory stems by shade tolerance. Stems consisted of shrubs, vines, and tree saplings > 1 m in height and a DBH < 2.54 cm. Restored (n=30) plots had less stems in the woody understory than unrestored (n=30) plots.



Appendix Figure 6. Woody understory stems by seed dispersal mode. Stems consisted of shrubs, vines, and tree saplings > 1 m in height and a DBH < 2.54 cm. Restored (n=30) plots had less stems in the woody understory than unrestored (n=30) plots.

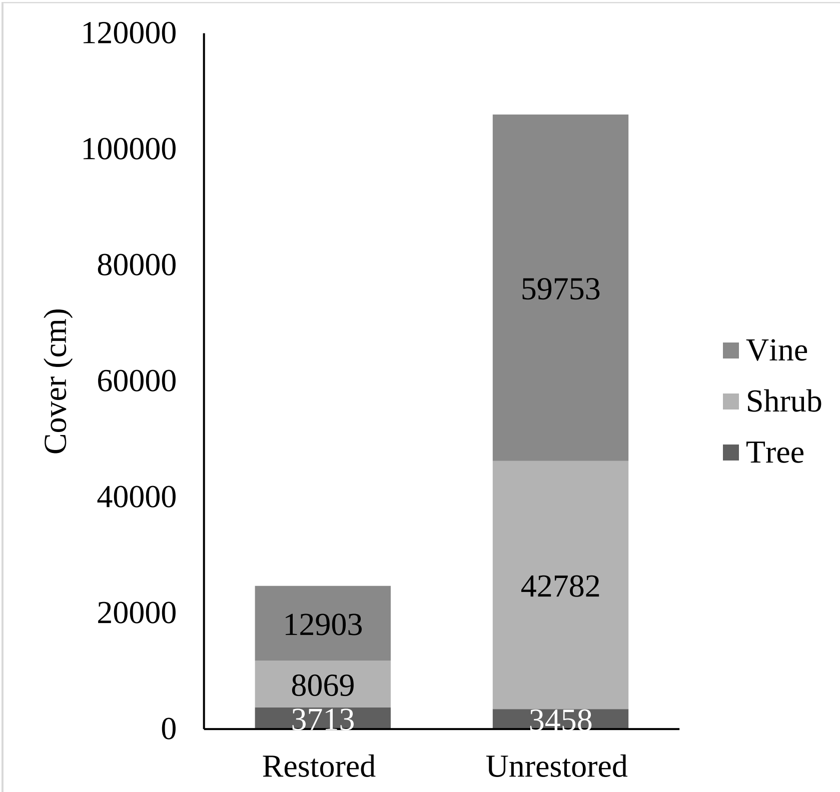


Appendix Figure 7. Woody understory stems by pollination syndrome. Stems consisted of shrubs, vines, and tree saplings > 1 m in height and a DBH < 2.54 cm.

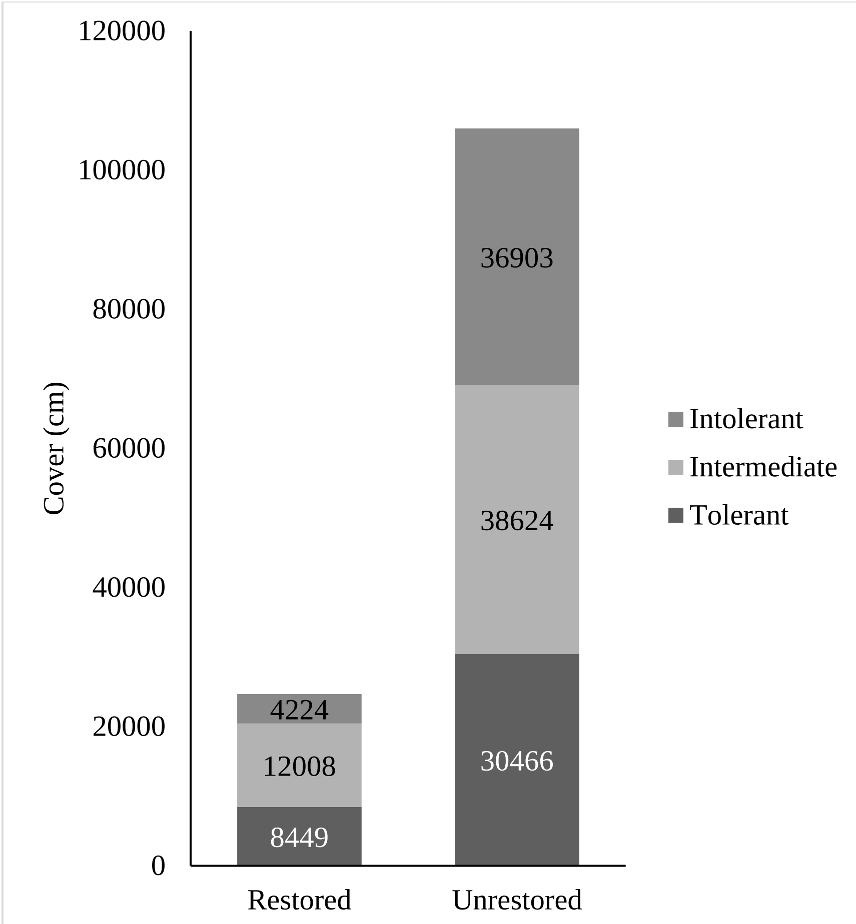


Appendix Figure 8. Tree stems in the woody understory by tree lifespan. Tree stems consisted of tree saplings > 1 m in height and a DBH < 2.54 cm. Restored (n=30) plots had less stems in the woody understory than unrestored (n=30) plots.

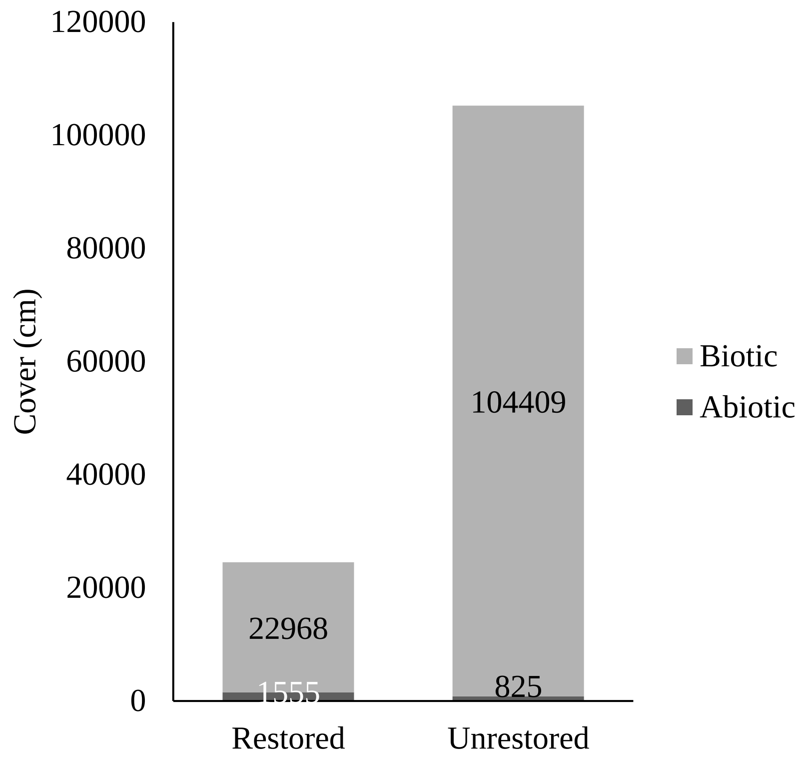
A.4.3 Functional Trait Composition by Cover of Woody Species in the Ground Layer



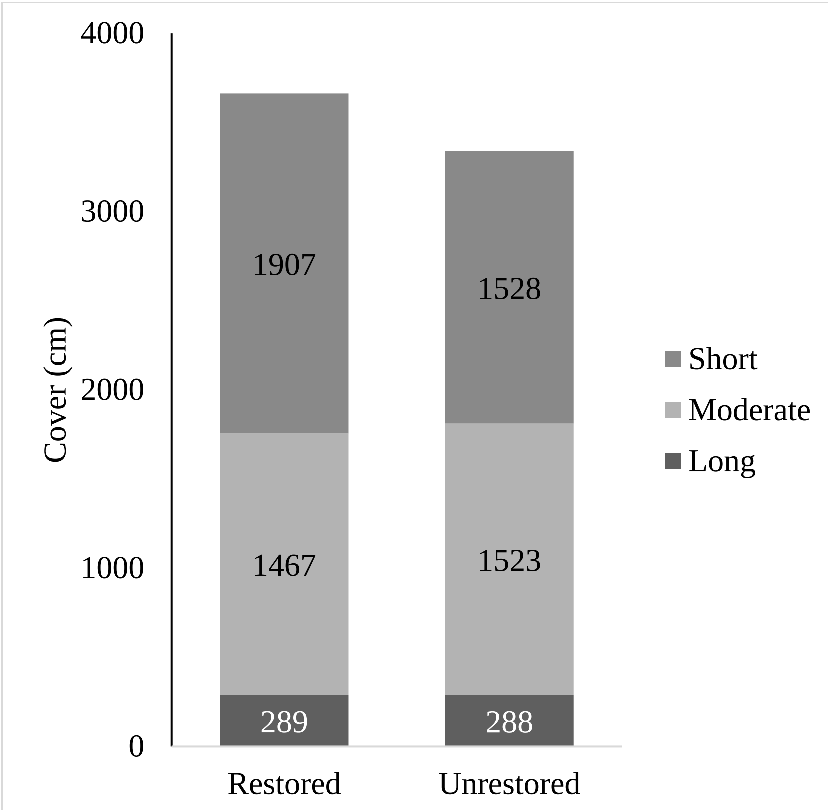
Appendix Figure 9. Woody species in the ground layer by growth form. Cover consisted of shrub, vine, and tree seedling species < 1 m in height. Restored (n=30) plots had less ground cover by woody species than unrestored (n=30) plots.



Appendix Figure 10. Woody species in the ground layer by shade tolerance. Cover consisted of shrub, vine, and tree seedling species < 1 m in height. Restored (n=30) plots had less ground cover by woody species than unrestored (n=30) plots.

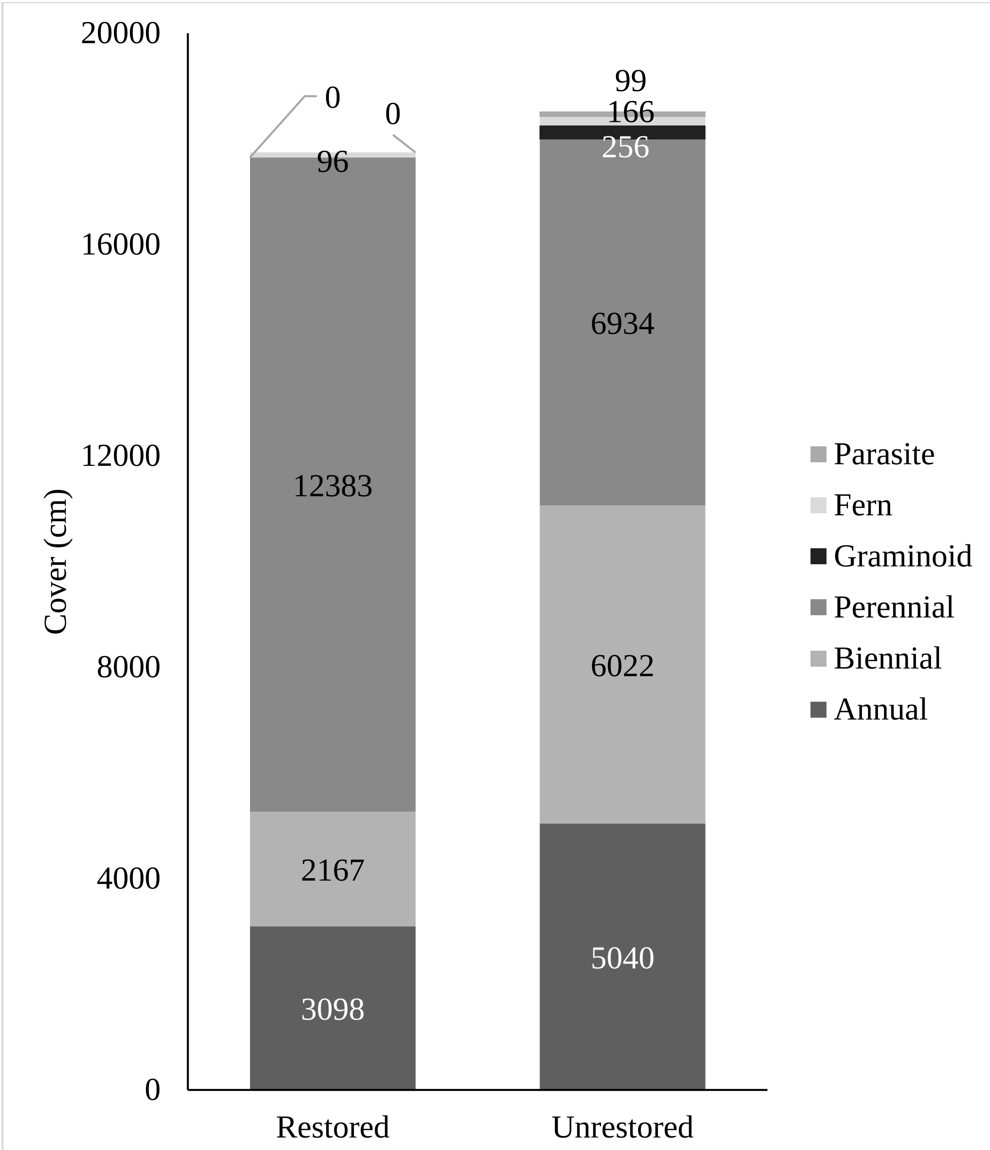


Appendix Figure 11. Woody species in the ground layer by pollination syndrome. Cover consisted of shrub, vine, and tree seedling species < 1 m in height. Restored (n=30) plots had less ground cover by woody species than unrestored (n=30) plots.

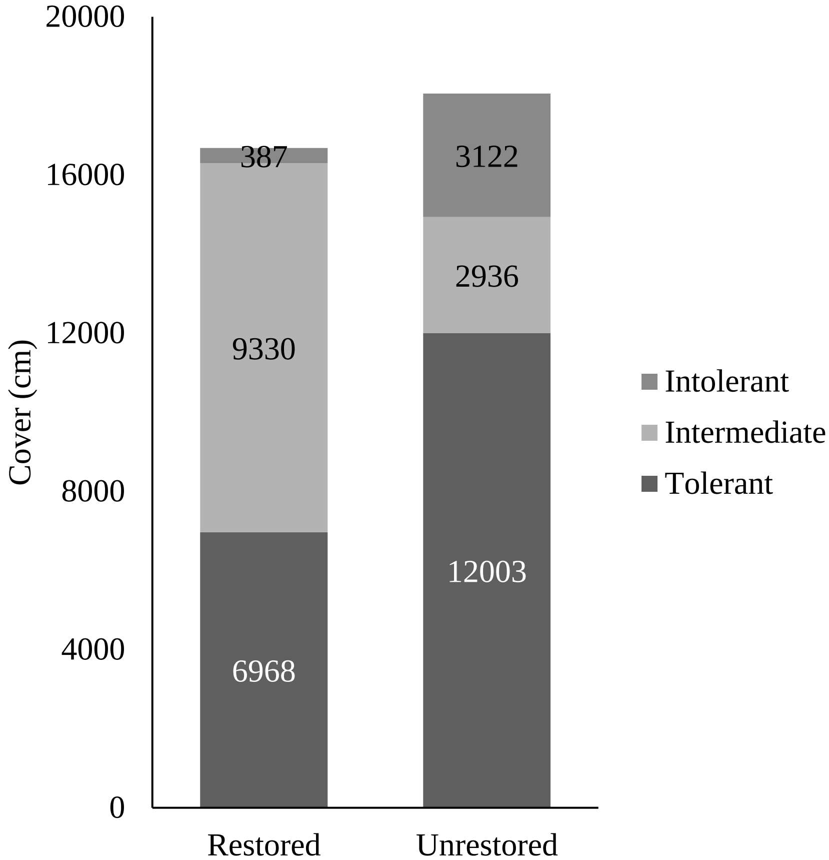


Appendix Figure 12. Tree seedlings in the ground layer by tree lifespan. Cover consisted of tree seedling species < 1 m in height. Restored (n=30) plots had greater ground cover by tree seedlings than unrestored (n=30) plots.

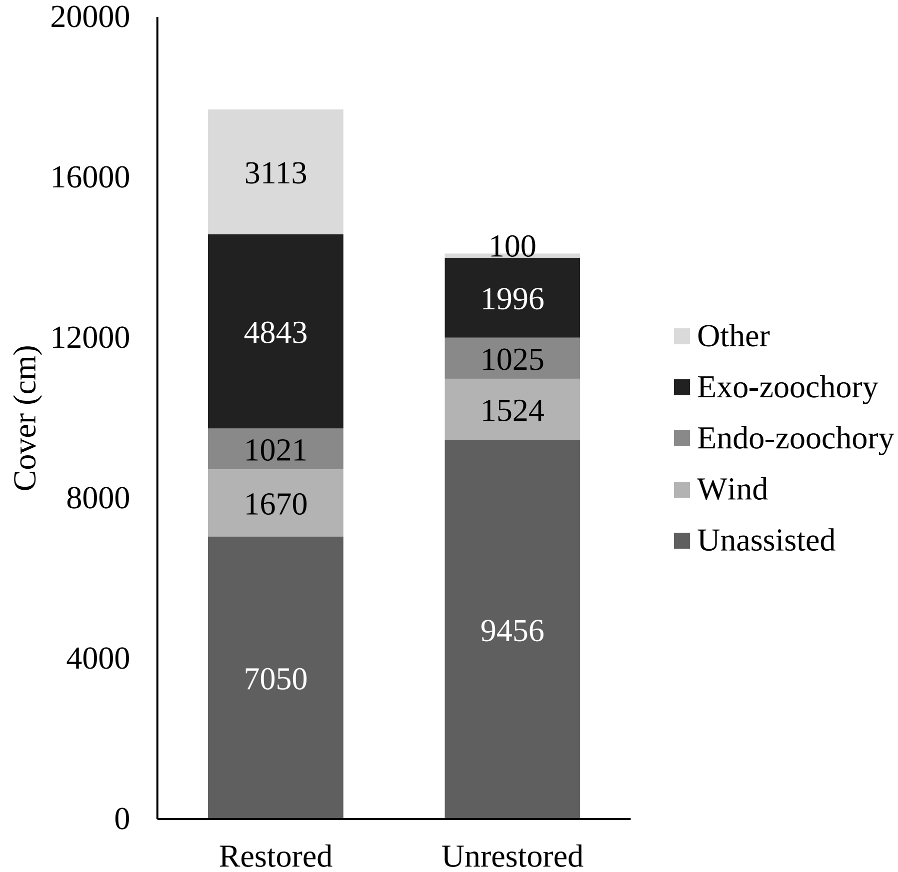
A.4.4 Functional Trait Composition by Cover of Herbaceous Species in the Ground Layer



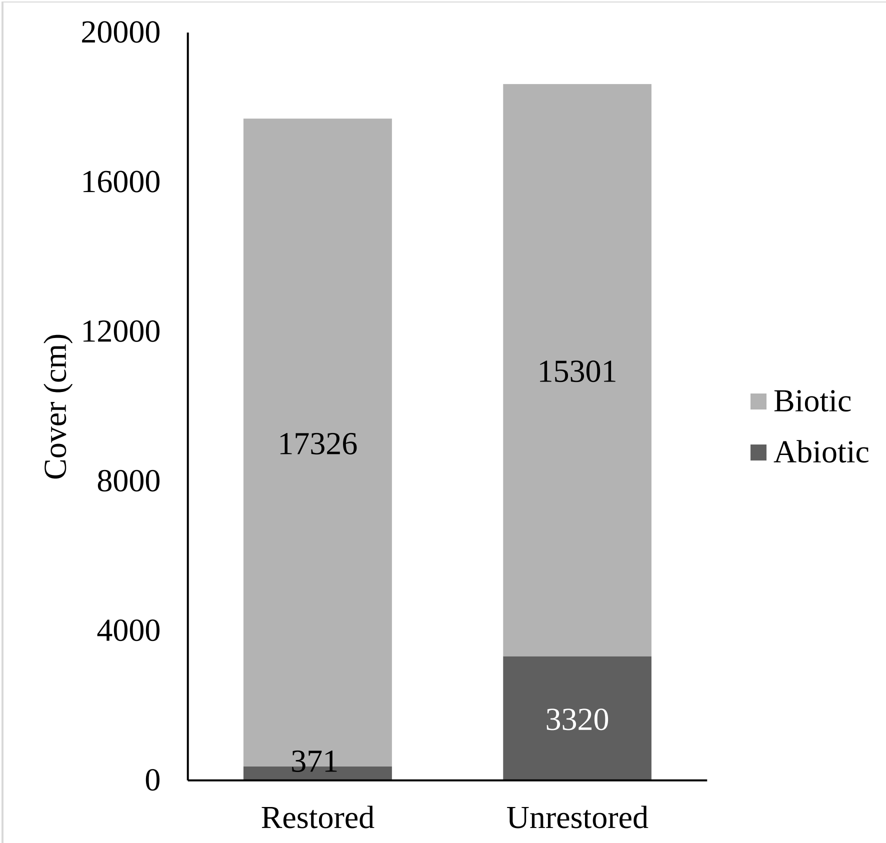
Appendix Figure 13. Herbaceous species in the ground layer by growth form. Herbaceous cover by perennial species was greater in restored (n=30) plots. Restored plots had less ground cover by herbaceous species than unrestored (n=30) plots.



Appendix Figure 14. Herbaceous species in the ground layer by shade tolerance. There was greater cover by herbaceous species with intermediate shade tolerance in restored (n=30) plots. Restored plots had less total ground cover by herbaceous species than unrestored (n=30) plots.

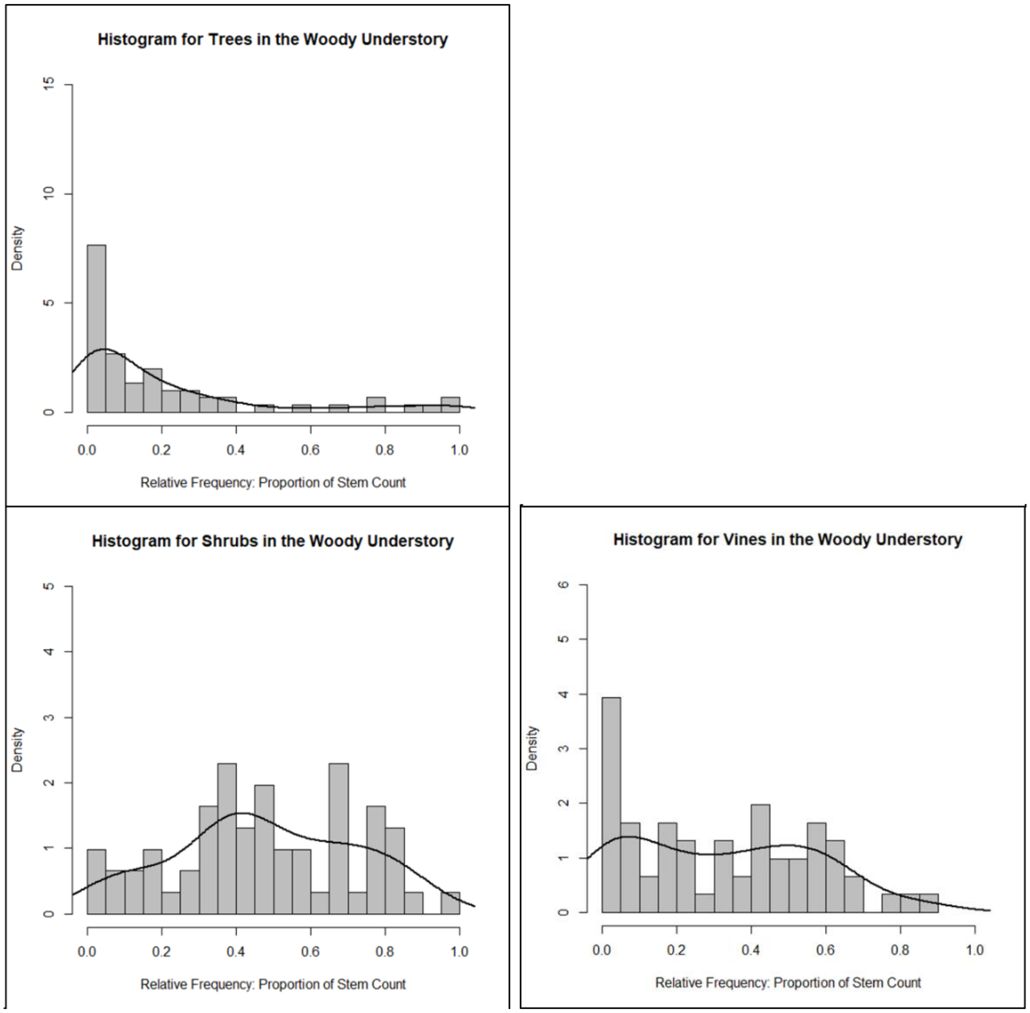


Appendix Figure 15. Herbaceous species in the ground layer by seed dispersal. There was greater cover by exozoochoric species in restored (n=30) plots.

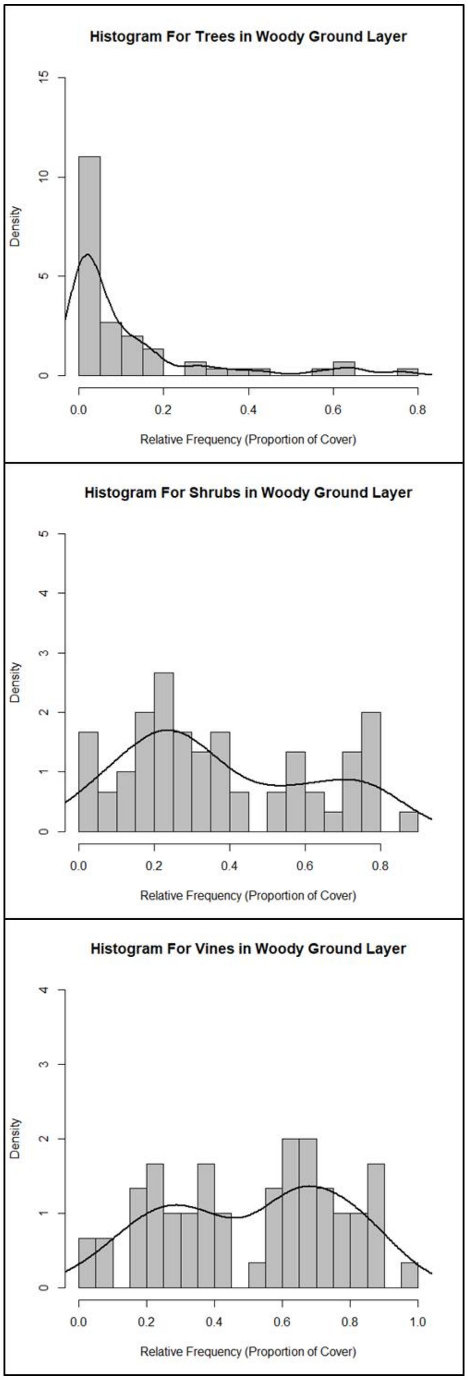


Appendix Figure 16. Herbaceous species in the ground layer by seed dispersal. There was greater cover by biotically pollinated herbaceous species in restored (n=30) and unrestored (n=30) plots.

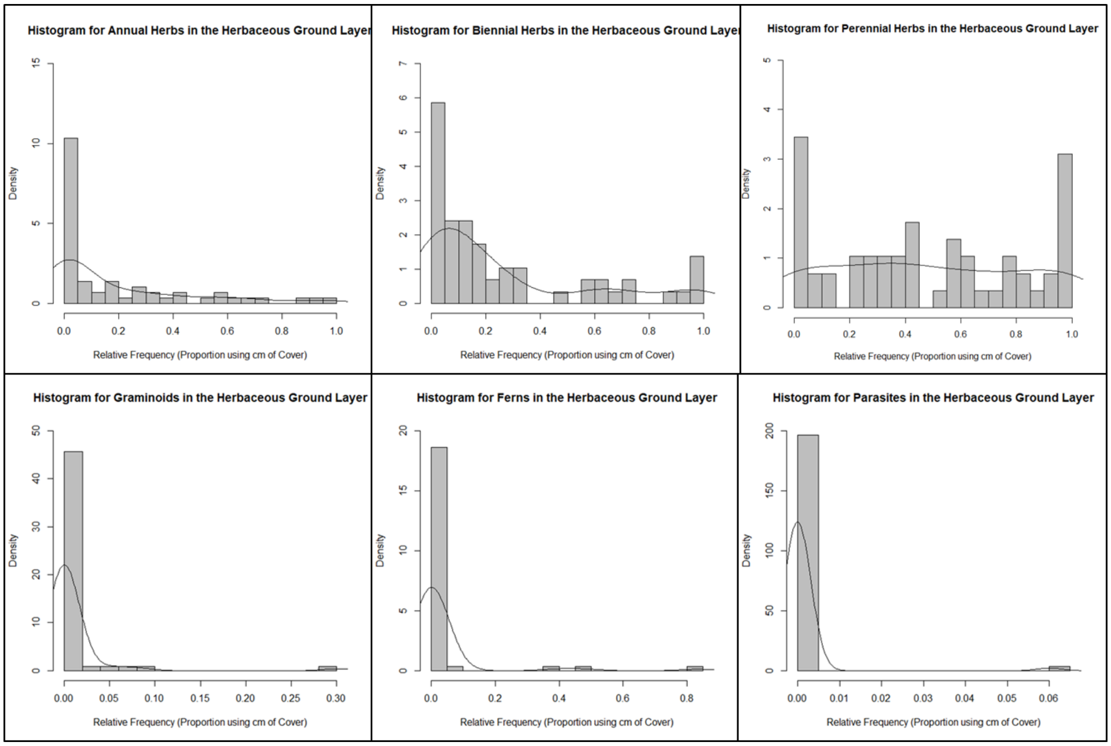
A.5 Histograms of Functional Trait Distribution



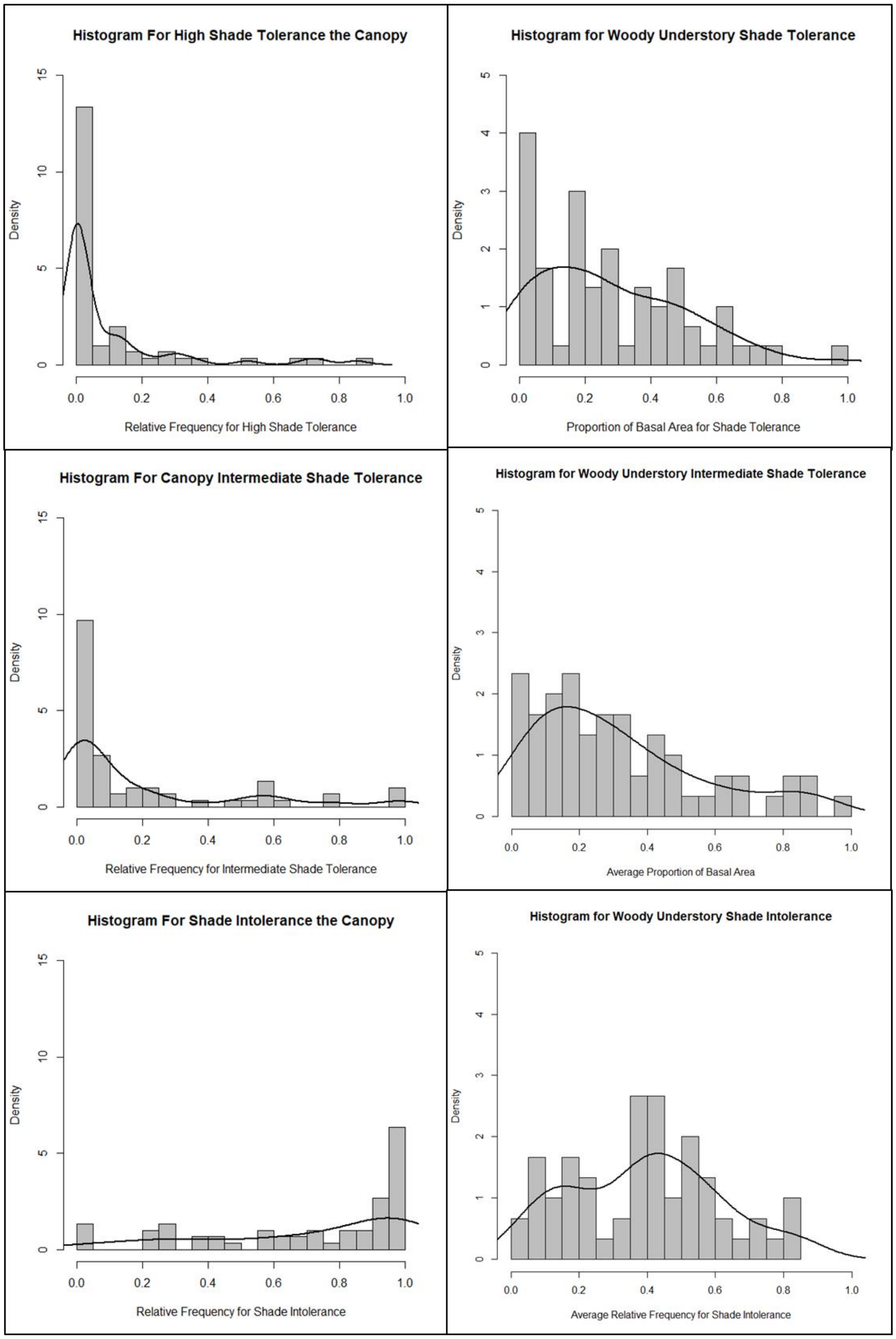
Appendix Figure 17. Histogram of growth forms in the woody understory of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



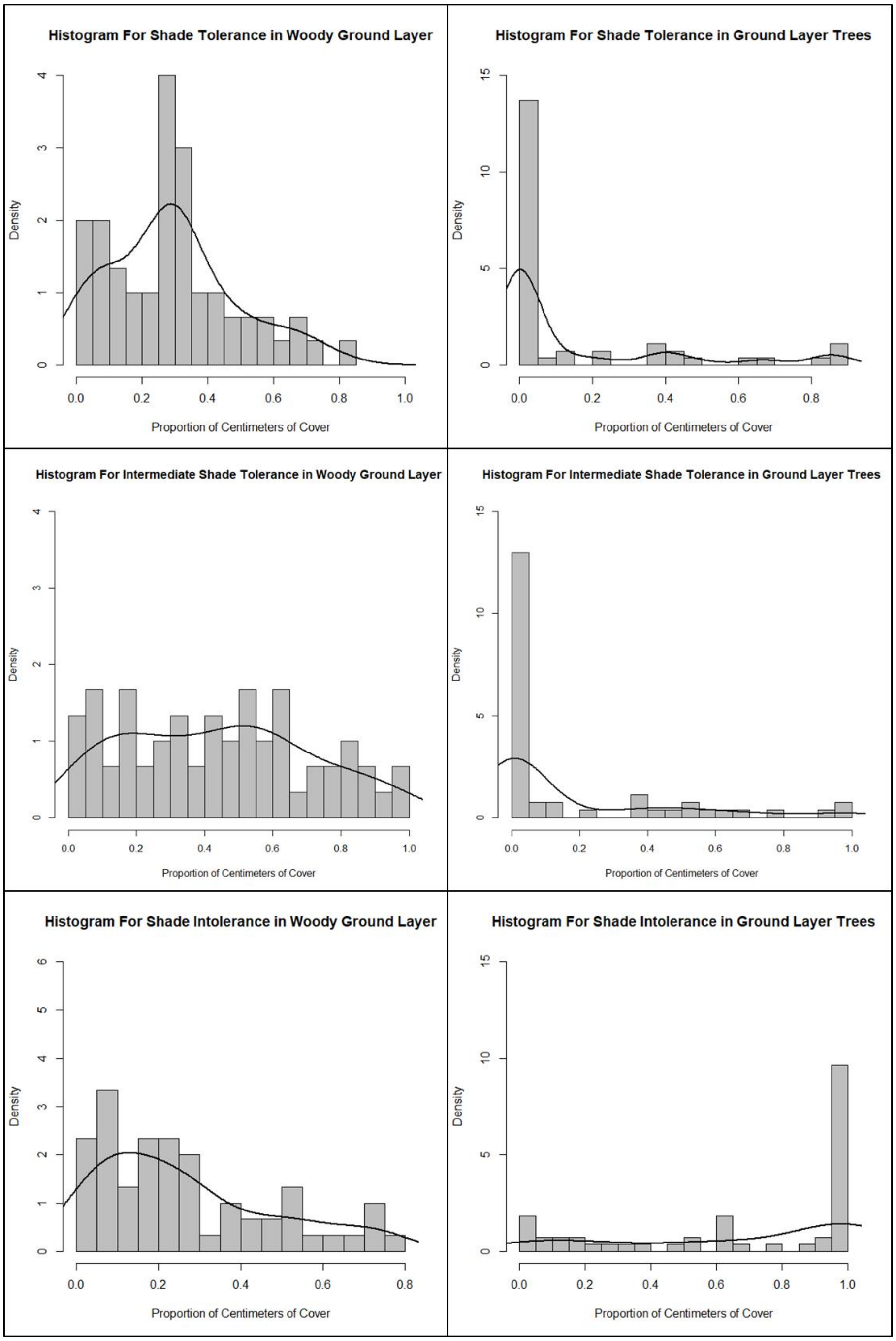
Appendix Figure 18. Histogram of growth forms among woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



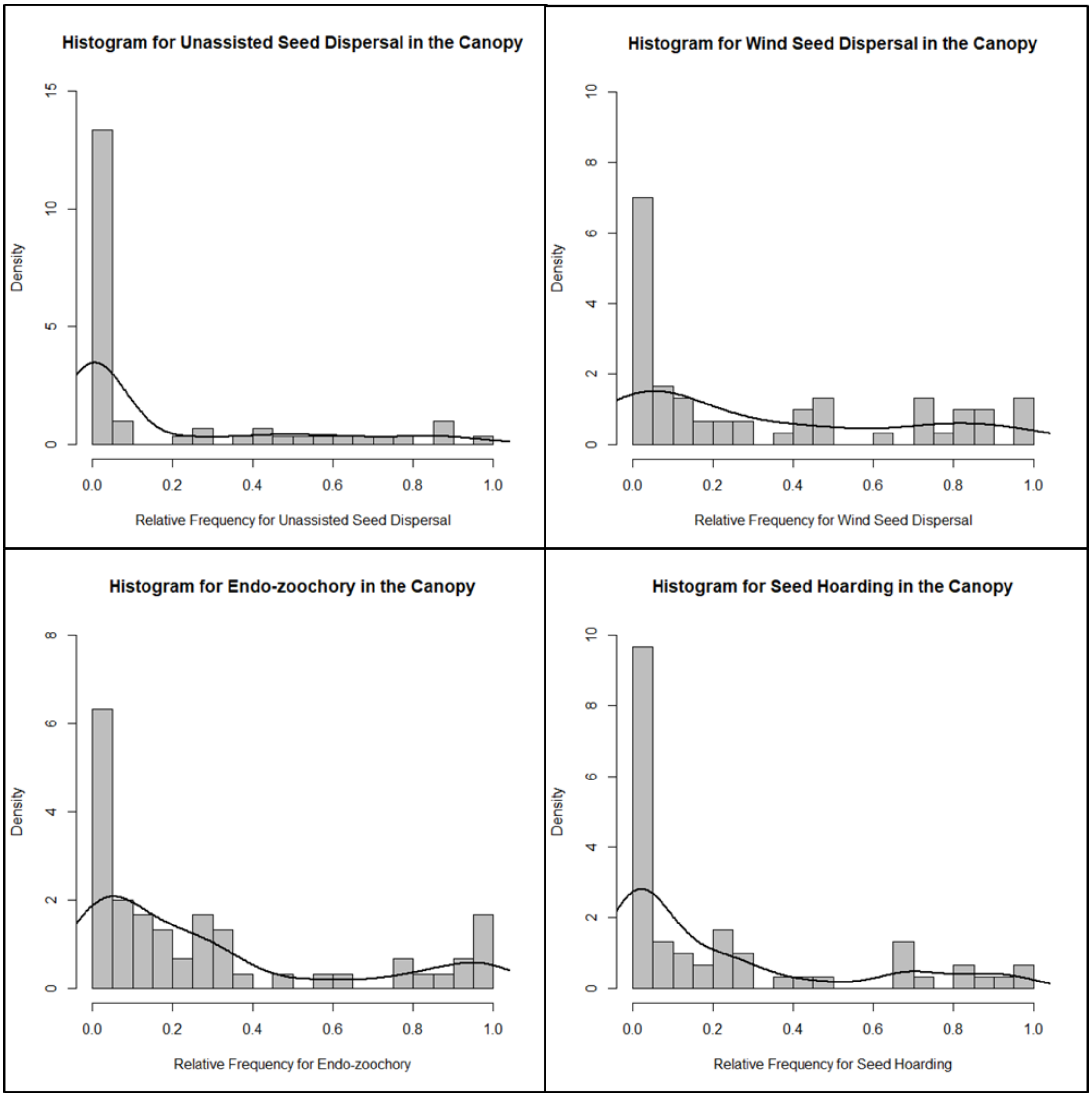
Appendix Figure 19. Histogram of herbaceous growth forms in the ground layers of restored (n=30) and unrestored plots (n=30).   Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



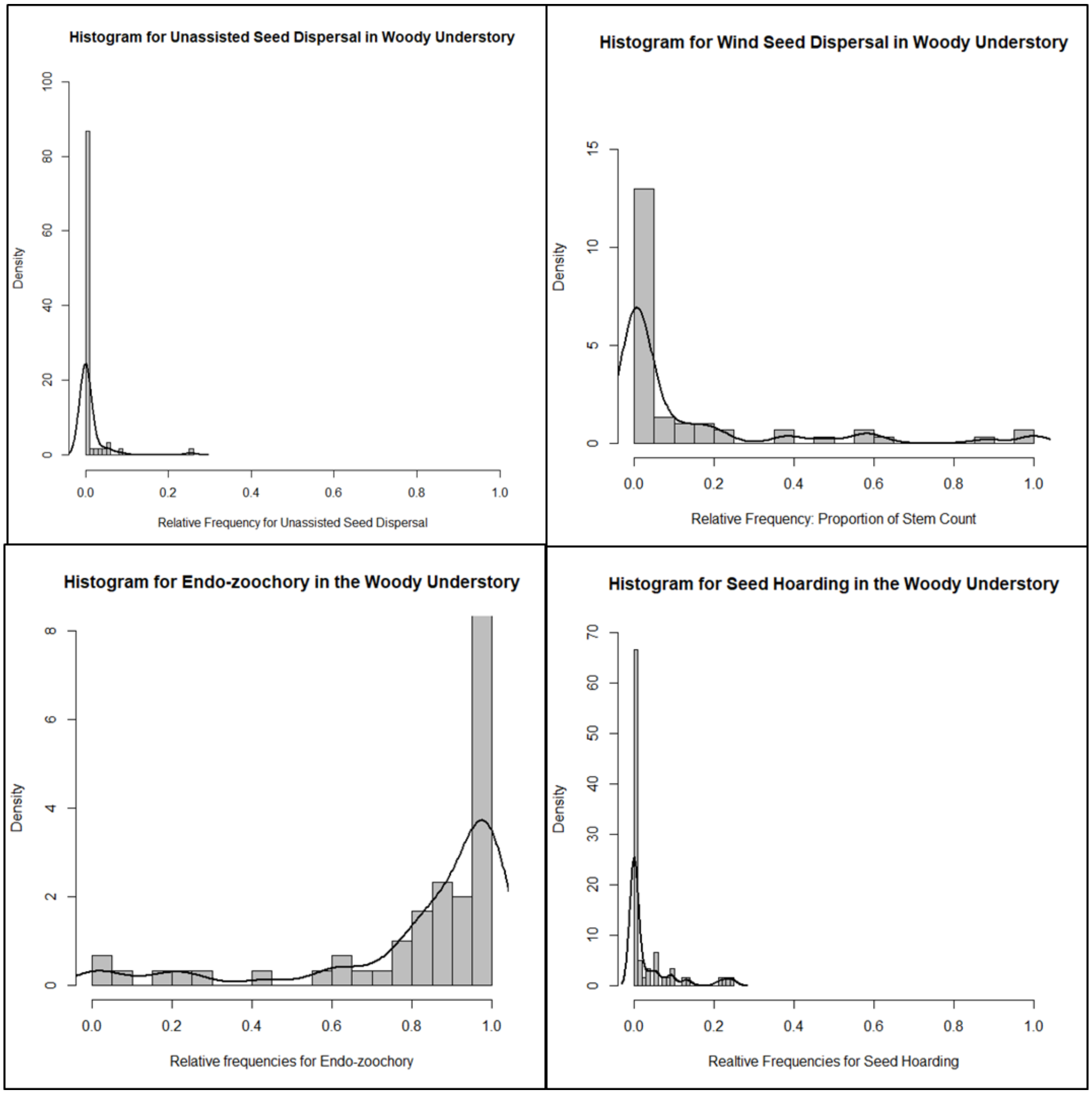
Appendix Figure 20. Histogram of shade tolerance among trees of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



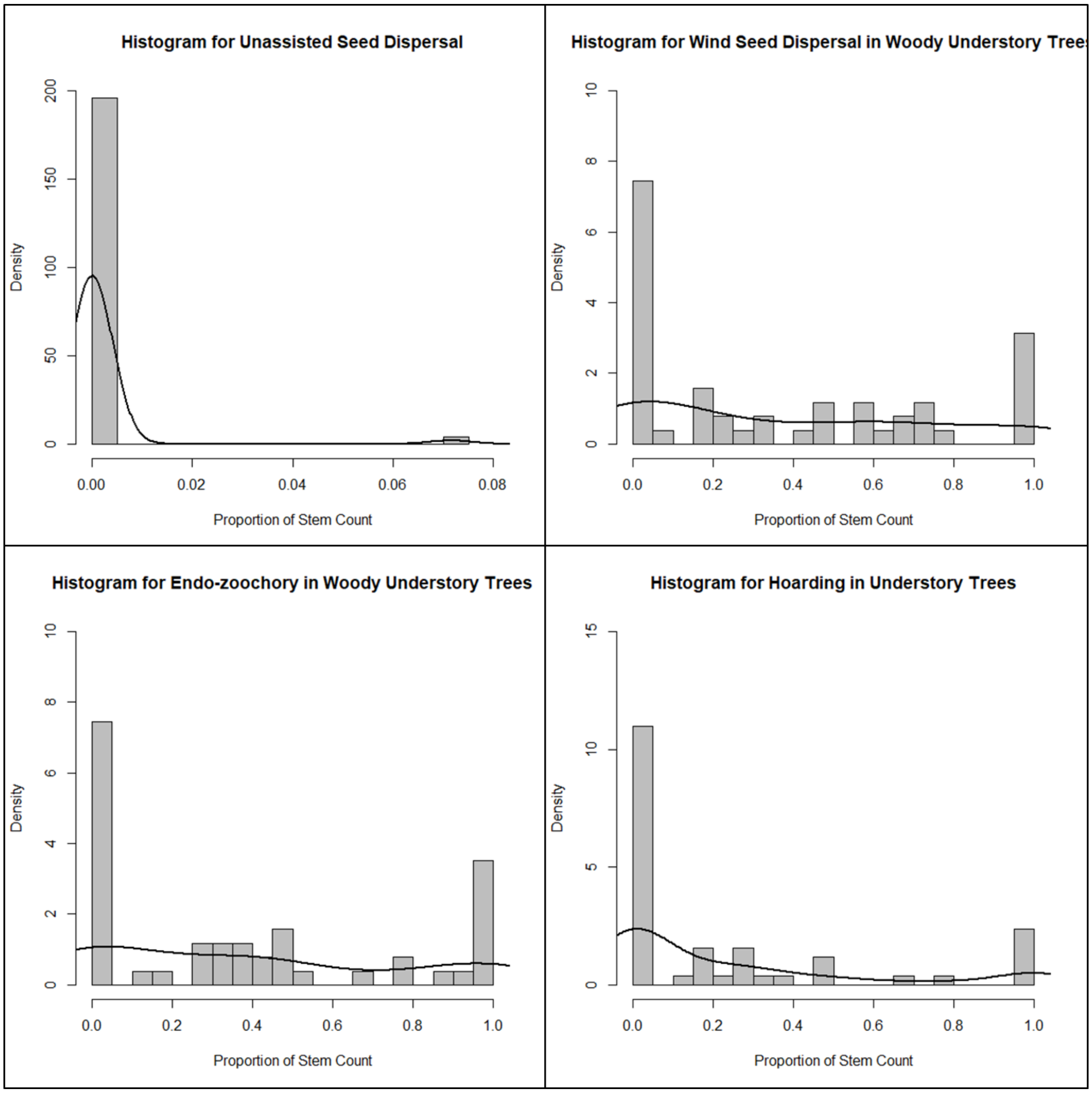
Appendix Figure 21. Histogram of shade tolerance among woody understory communities in restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



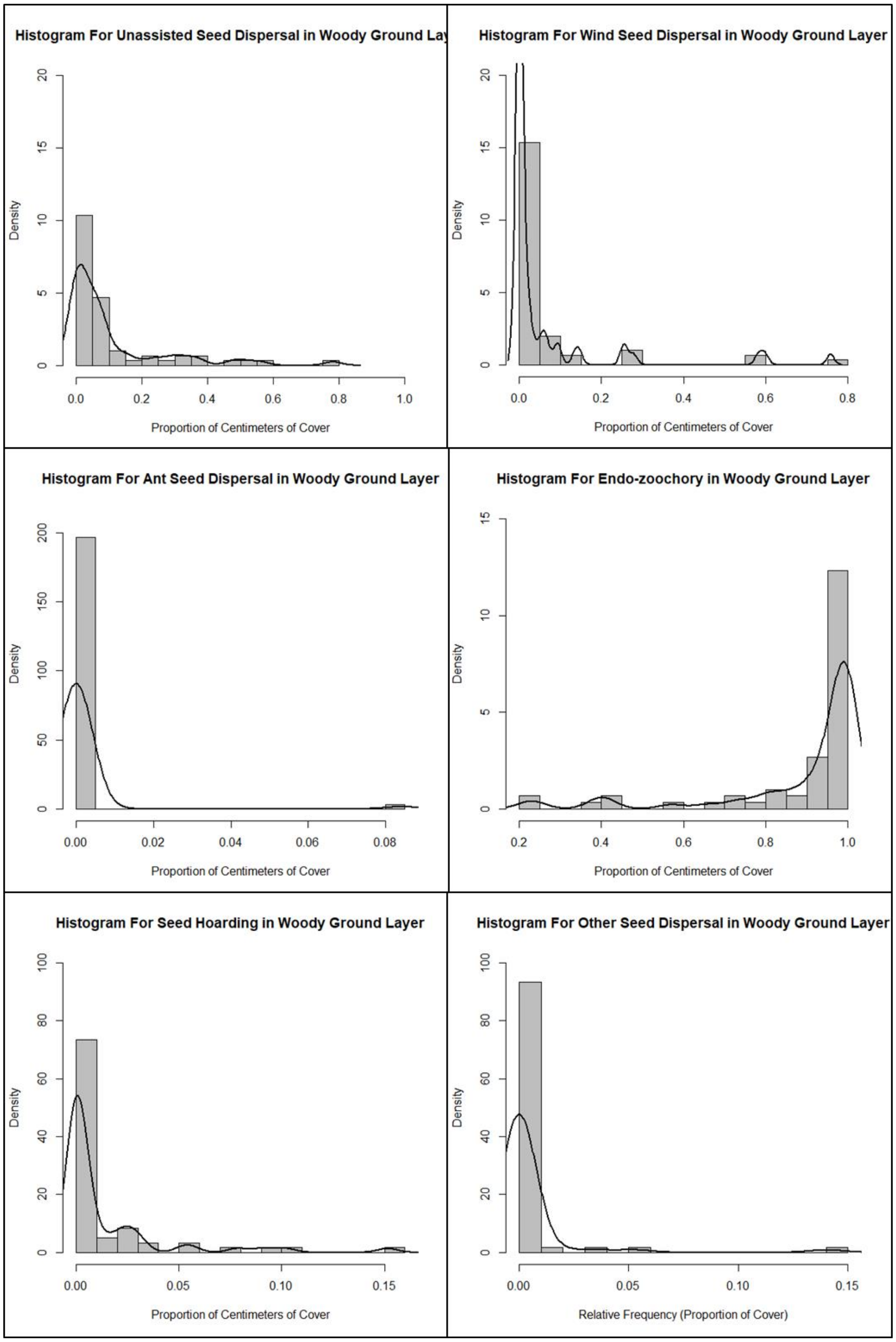
Appendix Figure 22. Histogram of seed dispersal among trees in restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



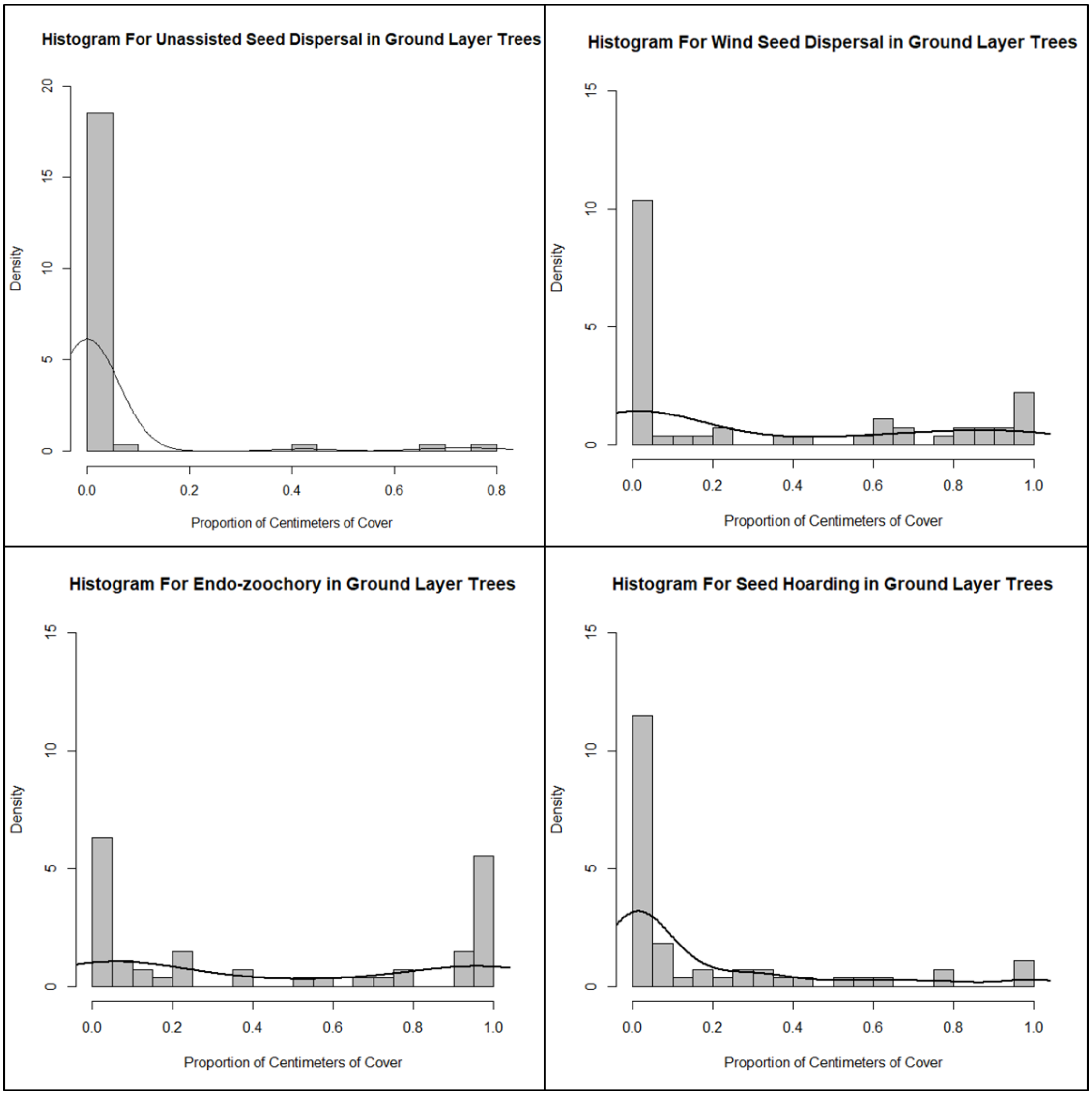
Appendix Figure 23. Histogram of seed dispersal among woody understory communities in restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



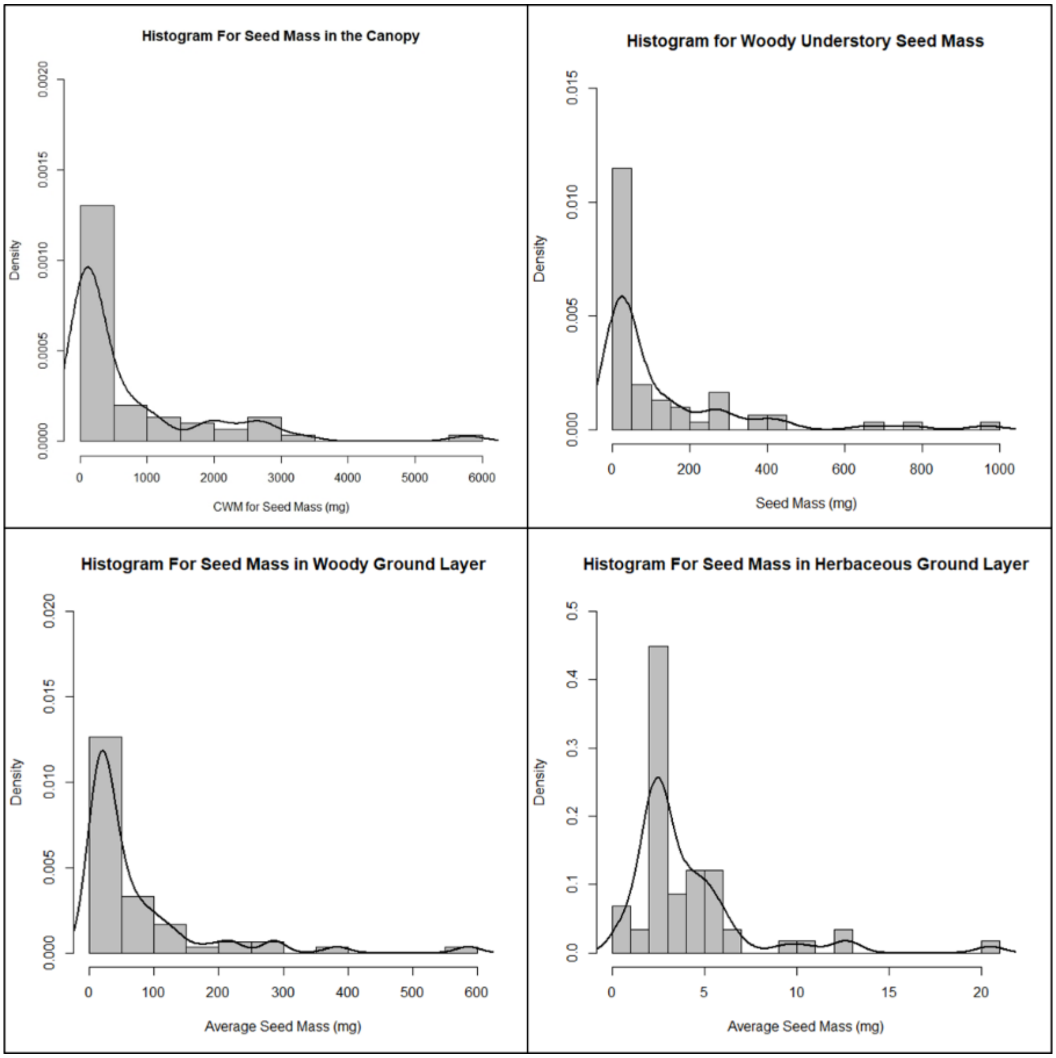
Appendix Figure 24. Histogram of seed dispersal among tree saplings in the woody understories of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



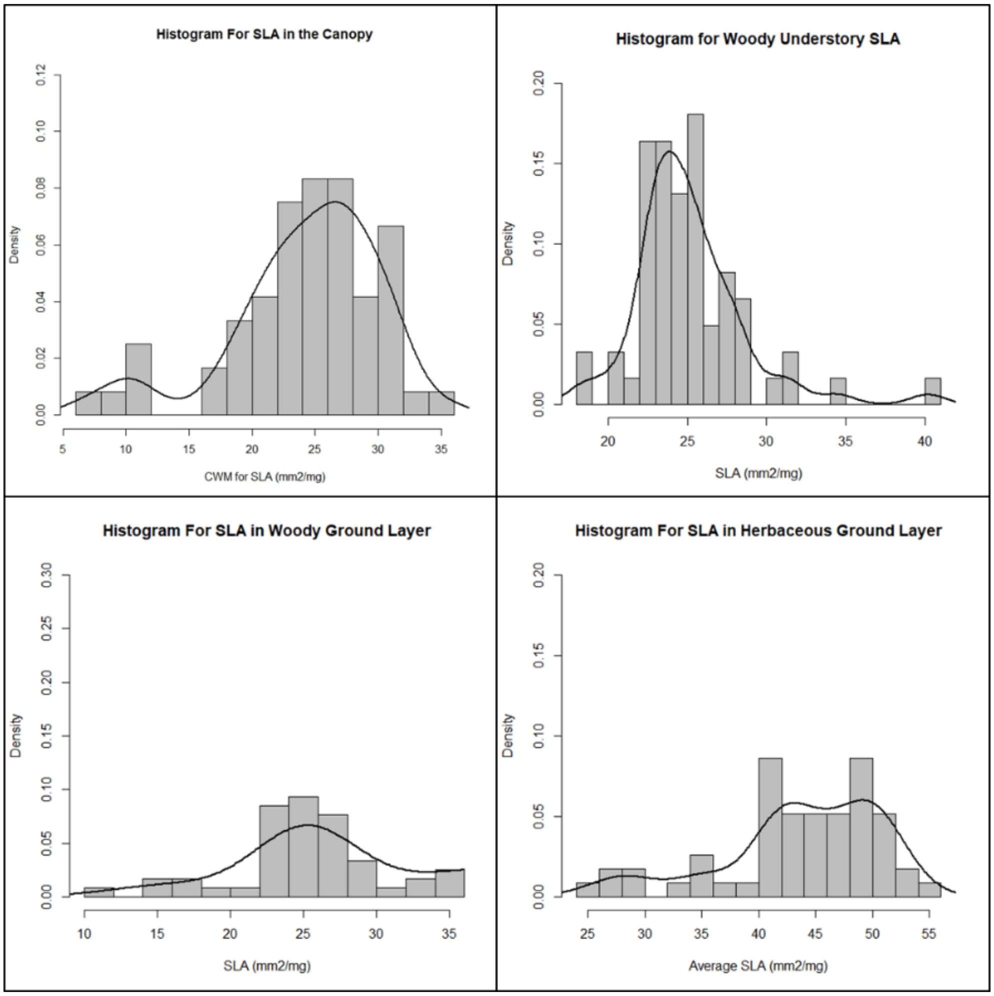
Appendix Figure 25. Histogram of seed dispersal among woody species in the ground layer of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



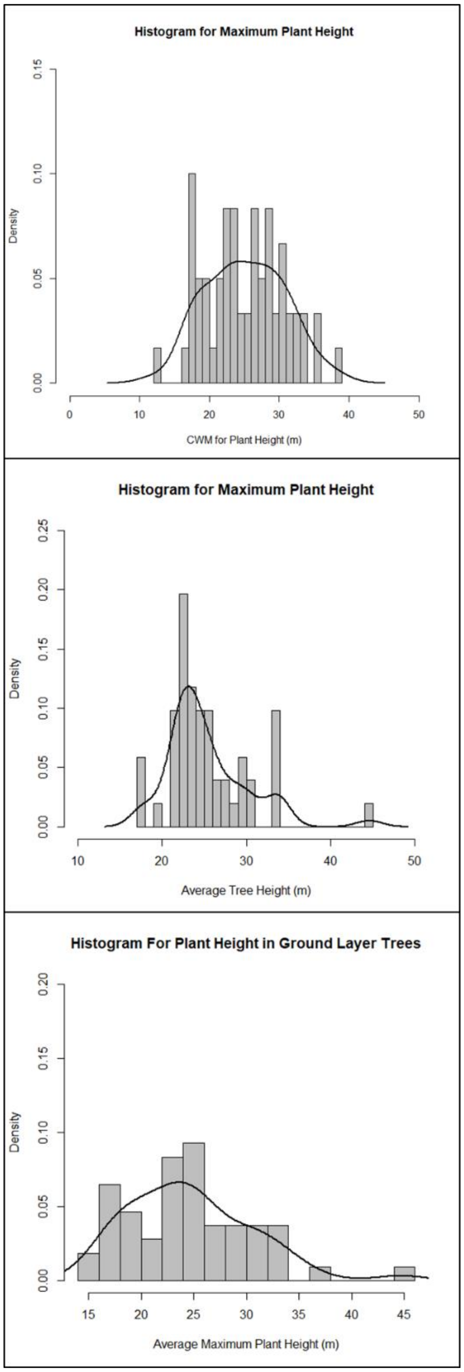
Appendix Figure 26. Histogram of seed dispersal among tree seedlings in the ground layer of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



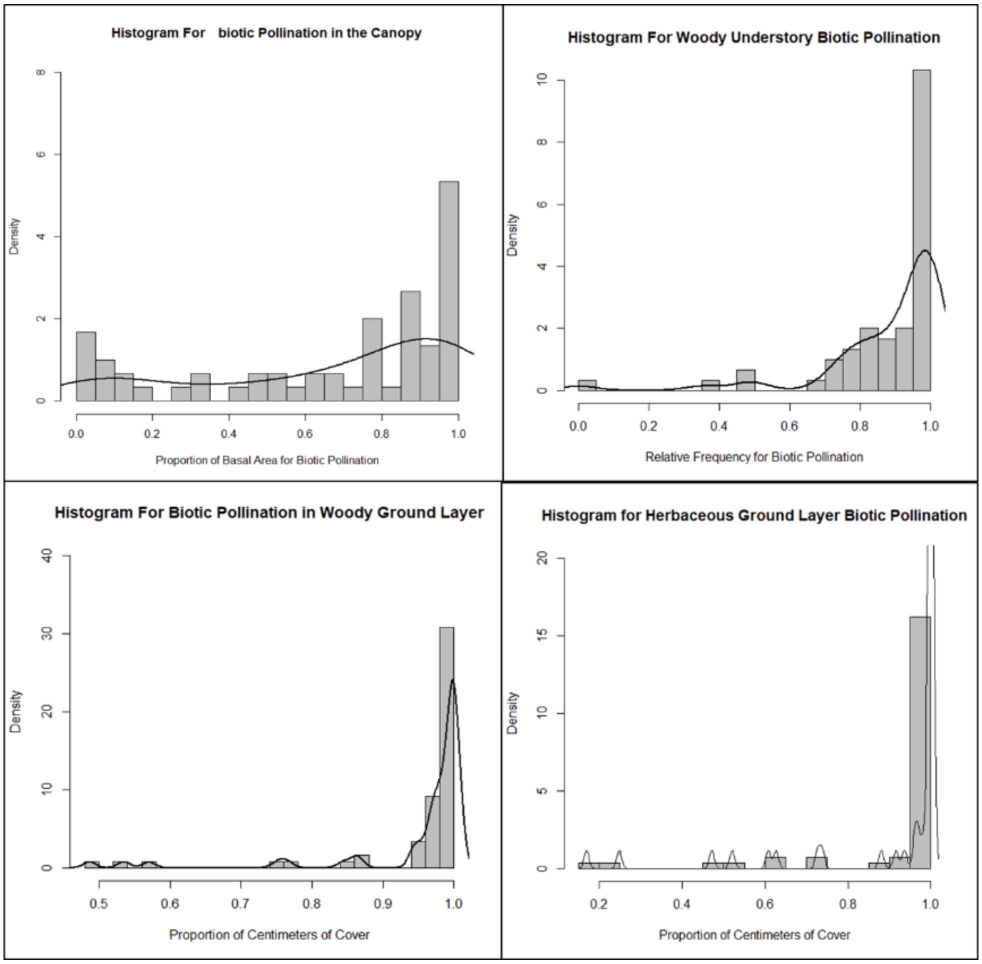
Appendix Figure 27. Distribution of average seed mass among communities in forest strata of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



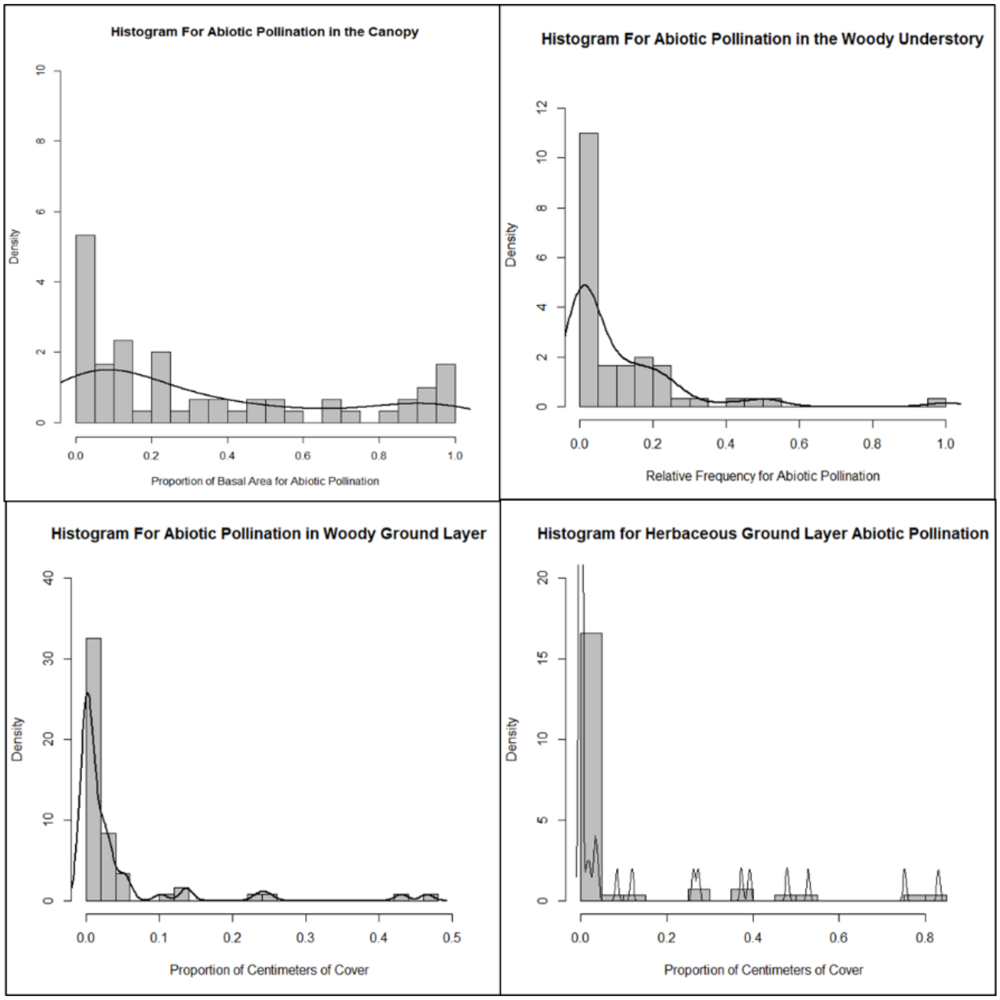
Appendix Figure 28. Distribution of average SLA among communities in forest strata of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



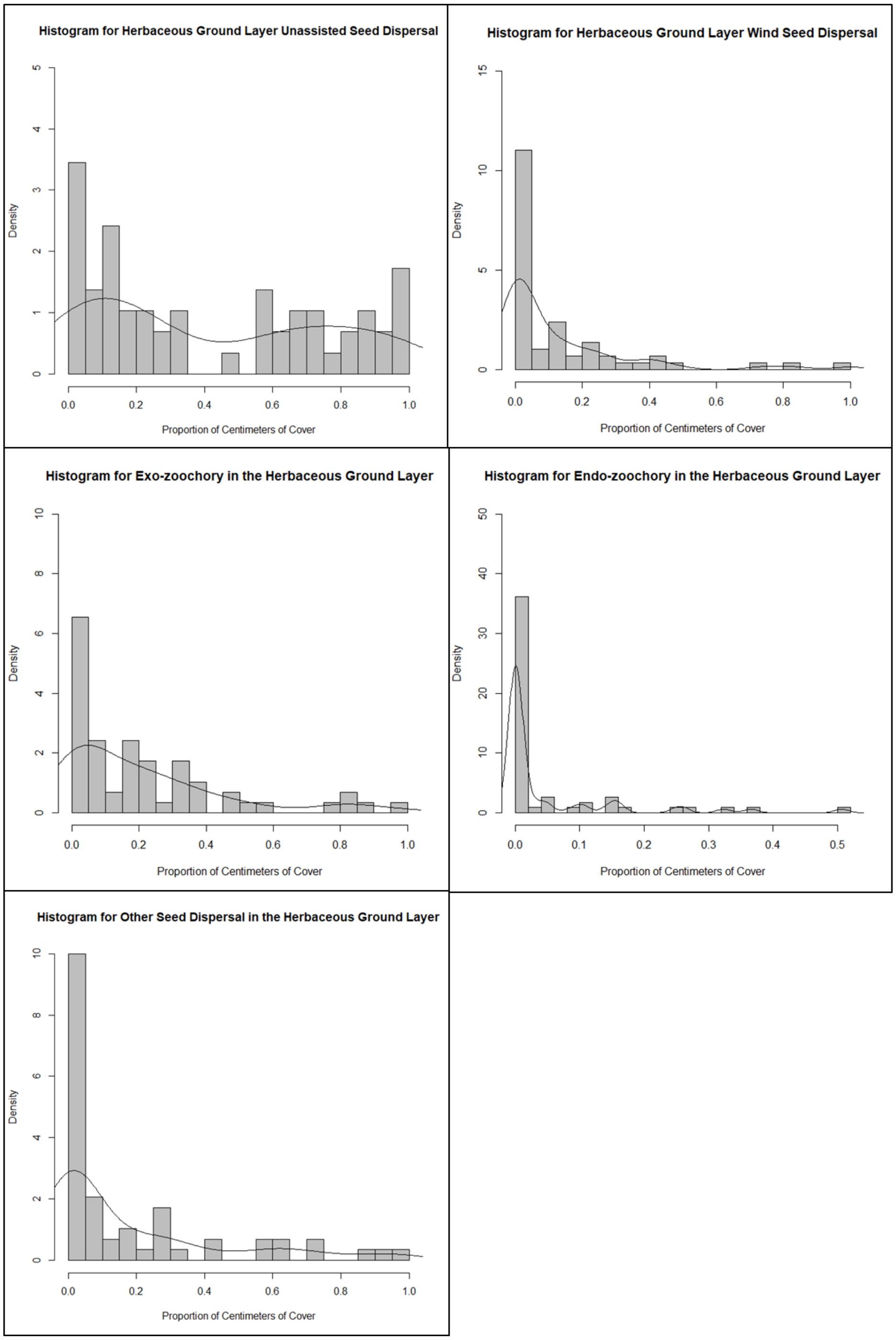
Appendix Figure 29. Distribution of average maximum tree height among communities in forest strata of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



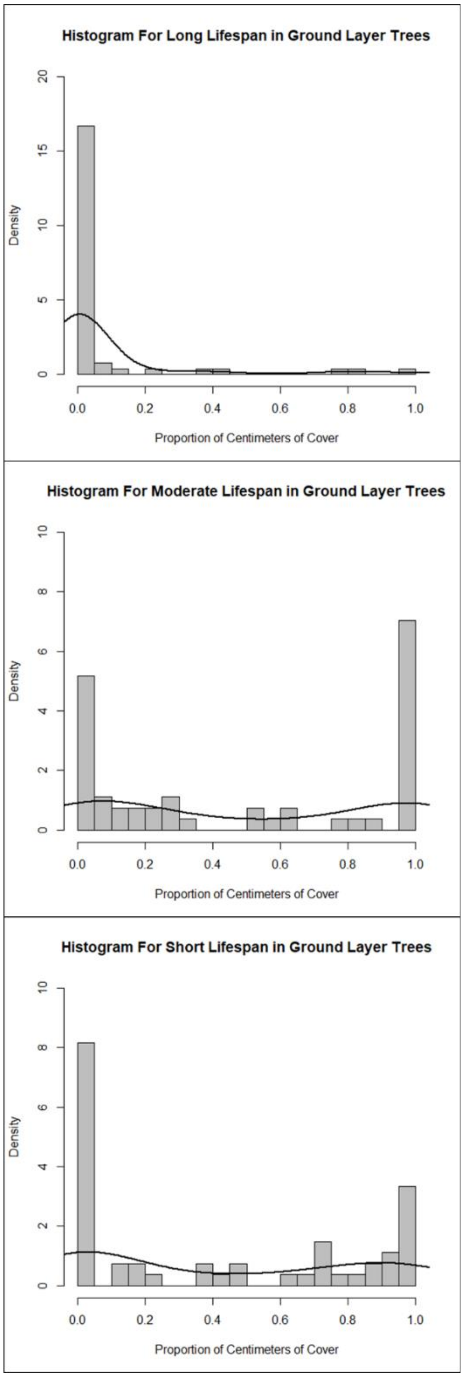
Appendix Figure 30. Distribution of biotic pollination among communities in forest strata of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



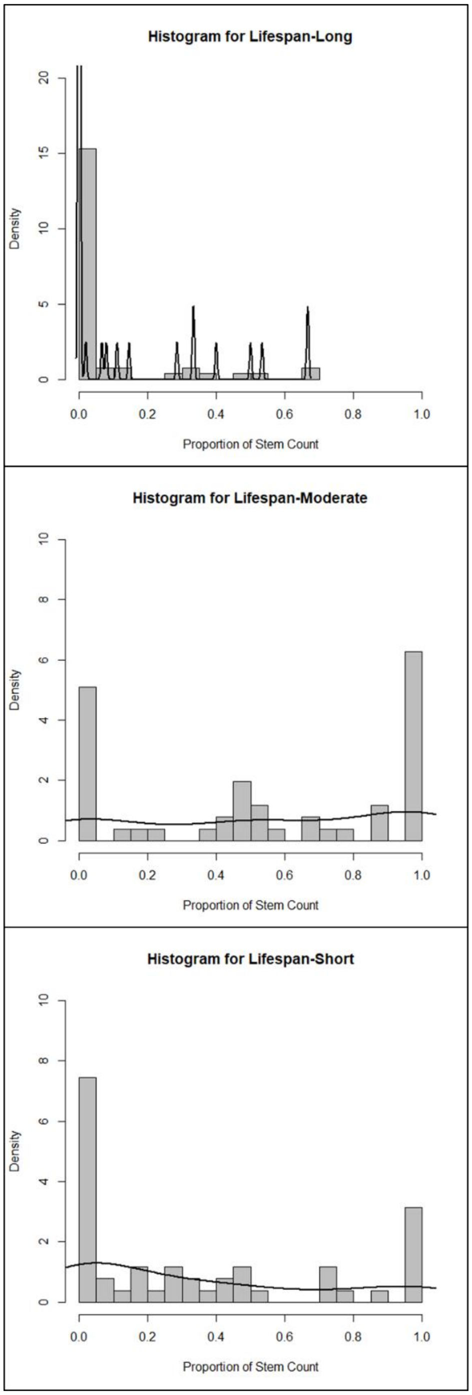
Appendix Figure 31. Distribution of abiotic pollination among communities in forest strata of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



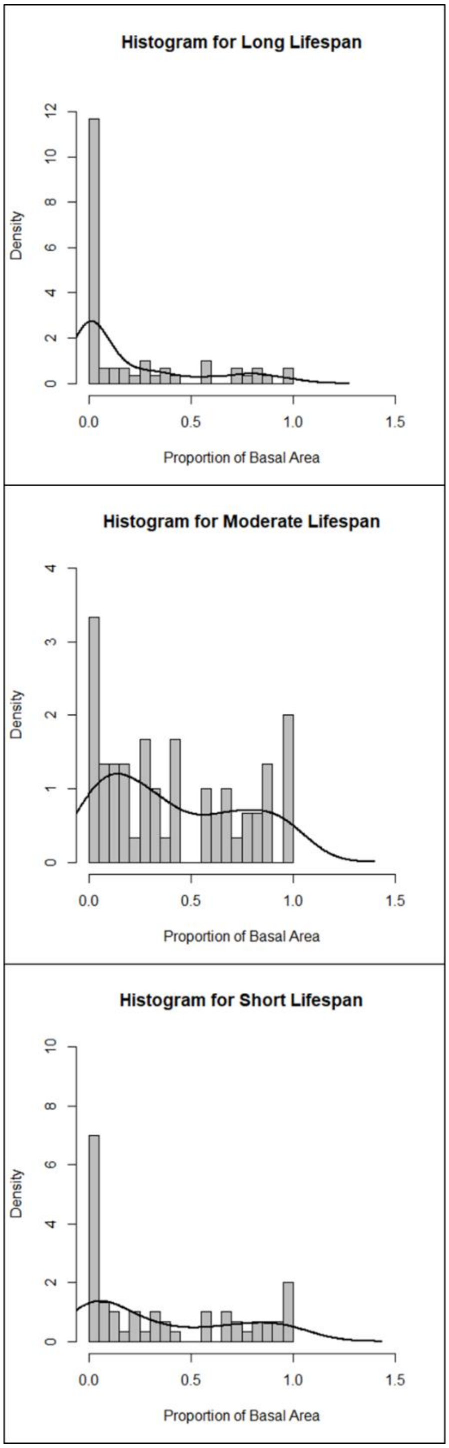
Appendix Figure 32. Distribution of seed dispersal in the communities of herbaceous species in the ground layers of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



Appendix Figure 33. Distribution of tree lifespan in the woody understory of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



Appendix Figure 34. Distribution of tree lifespan in the woody understory of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.



Appendix Figure 35. Distribution of tree lifespan in tree communities of restored (n=30) and unrestored plots (n=30). Bars represent the number of plots within a particular bin range. The curved line illustrates the normal density curve.

A.6 Descriptive Statistics

A.62. Descriptive statistics of the relative abundance of growth forms in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of relative abundances in restored and unrestored plots.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Woody Understory (% Stems)					
Tree	36.4	31.1	25.6	0	100
Shrub	46.9	27.8	46.8	0	96.3
Vine	16.7	19.7	9.5	0	66.8
Woody Ground Layer (% cm of cover)					
Tree	18.4	21.8	8.9	0	75.8
Shrub	33.0	23.6	24.7	0	78.1
Vine	48.7	27.0	48.7	0	100.0
Herbaceous Ground Layer (% cm of cover)					
Annual	16.6	23.4	2.3	0	86.5
Biennial	10.8	14.0	6.5	0	58.5
Perennial	69.6	30.1	82.4	0	100.0
Graminoid	0	0	0	0	0.0
Fern	3.0	15.2	0	0	83.1
Parasite	0	0	0	0	0.0
	Unrestored				
Woody Understory (% Stems)	4.9	6.0	2.6	0	2.6
Tree	48.3	21.8	44.5	4.8	84.9
Shrub	46.8	20.6	50.3	6.0	88.9
Vine					
Woody Ground Layer (% cm of cover)	4.2	6.0	1.6	0	27.8
Tree	42.1	25.7	36.8	3.2	87.6
Shrub	53.7	25.1	59.8	9.3	89.2
Vine					
Herbaceous Ground Layer (% cm of cover)	20.9	30.3	5.7	0	100.0

Annual	42.8	36.2	31.5	0	100.0
Biennial	31.2	29.2	28.4	0	100.0
Perennial	1.7	5.2	0	0	26.4
Graminoid	3.4	11.5	0	0	47.9
Fern	0.2	1.1	0	0	6.0
Parasite					

A.63. Descriptive statistics of the relative abundance of shade tolerance in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of relative abundances in restored and unrestored plots.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy (% Basal Area)					
Tolerant	12.5	19.2	3.4	0	85.2
Intermediate Tolerance	20.9	26.1	9.5	0	95.7
Intolerant	66.6	29.8	73.1	4.2	100
Woody Understory (% Stems)					
Tolerant	23.2	24.3	17.0	0	100
Intermediate Tolerance	37.8	27.6	30.5	0	97.2
Intolerant	38.7	23.6	41.2	0	85.0
Woody Ground Layer (% cm of cover)					
Tolerant	36.1	21.6	32.8	0	80.2
Intermediate Tolerance	49.9	26.7	48.8	8.8	100
Intolerant	14.0	9.8	13.0	0	34.5
Herbaceous Ground Layer (% cm of cover)					
Tolerant	41.9	31.6	39.1	0	100
Intermediate Tolerance	51.2	32.7	54.4	0	100
Intolerant	2.5	5.8	0	0	26.5
	Unrestored				
Canopy (% Basal Area)					
Tolerant	6.9	18.4	0.0	0	74.3
Intermediate Tolerance	17.9	30.7	1.3	0.0	100
Intolerant	75.2	33.5	93.3	0.0	100
Woody Understory (% Stems)					
Tolerant	33.5	21.0	29.7	3.0	79.6
Intermediate Tolerance	25.9	21.8	18.5	0.0	82.8
Intolerant	40.4	20.8	37.7	7.9	84.9
Woody Ground Layer (% cm of cover)					
Tolerant	33.0	16.3	32.4	1.6	68.5
Intermediate Tolerance	32.5	24.8	29.5	0.4	93.2
Intolerant	34.3	22.3	29.3	3.0	73.4

Herbaceous Ground Layer (% cm of cover)					
Tolerant	72.3	27.6	78.7	0	100
Intermediate Tolerance	17.0	21.0	11.2	0	100
Intolerant	7.9	18.5	0	0	75.2

A. 64. Descriptive statistics of the relative abundance of seed dispersal modes in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of relative abundances in restored and unrestored plots.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy (% Basal Area)					
Unassisted	18.4	30.0	0.3	0	89.0
Wind	37.4	34.3	32.6	0	99.9
Endo-zoochory	14.4	15.6	6.1	0	57.0
Hoarding	29.8	32.8	20.7	0	95.7
Woody Understory (% Stems)					
Unassisted	1.3	4.8	0	0	25.3
Wind	24.2	30.9	11.3	0	100
Endo-zoochory	67.1	31.1	80.7	0	97.4
Hoarding	5.9	8.0	1.2	0	25.0
Woody Ground Layer (% cm of cover)					
Unassisted	14.2	20.9	4.3	0	78.1
Wind	10.2	16.8	1.4	0	59.9
Endo-zoochory	73.1	25.1	80.2	12.2	100
Hoarding	2.1	3.6	0.01	0	15.2
Ants	0.3	1.5	0	0	8.4
Other	0.1	0.5	0	0	2.7
Herbaceous Ground Layer (% cm of cover)					
Unassisted	31.0	31.9	15.6	0	100
Wind	13.4	21.2	2.7	0	83.0
Endo-zoochory	7.1	13.4	0	0	50.7
Exo-zoochory	30.2	28.4	20.8	0	100
Other	8.3	23.7	8.3	0	86.5
	Unrestored				
Canopy (% Basal Area)					
Unassisted	16.4	29.1	0	0	100
Wind	26.8	34.9	9.9	0.0	100
Endo-zoochory	42.8	39.9	23.9	0.0	100
Hoarding	14.0	25.6	0.8	0	84.1
Woody Understory (% Stems)					

Unassisted	0.7	1.9	0	0	8.6
Wind	1.3	3.9	0	0	20.3
Endo-zoochory	97.0	5.1	99.2	79.7	100
Hoarding	0.57	1.3	0	0	5.7
Woody Ground Layer (% cm of cover)					
Unassisted	7.1	8.6	5.1	0	30.1
Wind	0	1.2	0	0	5.1
Endo-zoochory	91.8	9.7	84.5	66.8	100
Hoarding	0.4	1.0	0	0	4.4
Ants	0	0	0	0	0
Other	0.1	0.8	0	0	4.6
Herbaceous Ground Layer (% cm of cover)					
Unassisted	51.9	35.4	56.9	0	100
Wind	12.4	21.5	2.8	0	100
Endo-zoochory	4.4	7.9	0	0	26.1
Exo-zoochory	11.3	13.7	6.1	0	50.4
Other	19.6	30.2	5.7	0	100

A.65. Descriptive statistics of the relative abundance of pollination syndromes in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of relative abundances in restored and unrestored plots.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy (% Basal Area)					
Abiotic	40.6	33.4	32.7	0	96.5
Biotic	59.4	33.4	67.3	3.6	100.0
Woody Understory (% Stems)					
Abiotic	19.6	20.4	16.2	0	100
Biotic	79.2	21.6	83.0	0	100.0
Woody Ground Layer (% cm of cover)					
Abiotic	7.3	12.5	2.2	0	46.5
Biotic	91.4	14.9	97.9	48.6	100
Herbaceous Ground Layer (% cm of cover)					
Abiotic	3.8	15.7	0	0	83
Biotic	96.0	15.7	100.0	17.0	100
	Unrestored				
Canopy (% Basal Area)					
Abiotic	25.5	34.2	9.5	0	99.7
Biotic	74.5	34.2	90.6	0.3	100
Woody Understory (% Stems)					
Abiotic	1.7	3.5	0	0	15.3
Biotic	97.9	3.7	100	84.7	100
Woody Ground Layer (% cm of cover)					
Abiotic	1.0	1.6	0.2	0	5.6
Biotic	98.4	3.1	99.8	84.4	100
Herbaceous Ground Layer (% cm of cover)					
Abiotic	11.1	20.4	0	0	75
Biotic	89.4	19.8	100	24.8	100

A.66. Descriptive statistics of the relative abundance of tree lifespans in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of relative abundances in restored and unrestored plots.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy (% Basal Area)					
Long	21.6	26.8	12.8	0	95.8
Moderate	46.3	32.3	41.1	0	100
Short	28	33	13	0	99
Woody Understory (% Stems)					
Long	11.7	19.7	0	0	66.7
Moderate	63.4	33.6	66.7	0	100
Short	22	26	17	0	100
Woody Ground Layer (% cm of cover)					
Long	7.0	17.5	0	0	75.9
Moderate	55.4	43.5	61.8	0	100
Short	35.3	40.1	18.0	0	100
	Unrestored				
Canopy (% Basal Area)					
Long	18.1	33.2	0	0	100
Moderate	37.0	34.4	26.5	0	100
Short	43	39	35	0	100
Woody Understory (% Stems)					
Long	3.2	14.6	0	0	66.7
Moderate	43.1	46.9	20.0	0	100
Short	52	45.0	71.4	0	100
Woody Ground Layer (% cm of cover)					
Long	7.7	24.5	0	0	100
Moderate	43.8	42.6	26.7	0	100
Short	47.0	42.9	42.1	0	100

A.67. Descriptive statistics of the relative abundance of functional diversity indices in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of functional index scores in restored and unrestored plots. Functional diversity indices used in this study were functional richness (FRic), functional evenness (FEve) and functional divergences (FDiv).

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Combined Canopy and Woody Understory					
FRic	0.05	0.03	0.05	0.001	0.11
FEve	0.57	0.15	0.60	0.15	0.83
FDiv	0.80	0.12	0.81	0.58	0.97
Combined Ground Layer					
FRic	0.04	0.02	0.05	0.001	0.10
FEve	0.60	0.13	0.62	0.26	0.79
FDiv	0.77	0.11	0.77	0.57	0.98
	Unrestored				
Combined Canopy and Woody Understory					
FRic	0.05	0.03	0.04	0.001	0.01
FEve	0.49	0.14	0.48	0.18	0.78
FDiv	0.81	0.09	0.81	0.67	0.95
Combined Ground Layer					
FRic	0.04	0.03	0.04	0.005	0.10
FEve	0.49	0.10	0.50	0.16	0.64
FDiv	0.81	0.08	0.82	0.57	0.65

A.68. Descriptive statistics of the relative abundance of average seed mass in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of average seed mass in restored and unrestored plots. Average seed mass of a community was calculated using community weighted means (CWM), which used species abundance and average seed mass for each species.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy					
Average Seed Mass (mg)	887.7	1242.0	372.7	21.8	5777.9
Woody Understory					
Average Seed Mass (mg)	207.4	241.9	110.5	7.0	964.3
Woody Ground Layer					
Average Seed Mass (mg)	91.6	120.0	52.7	6.0	585.9
Herbaceous Ground Layer					
Average Seed Mass (mg)	5.5	4.4	4.2	0.2	20.5
	Unrestored				
Canopy					
Average Seed Mass (mg)	556.9	932.8	98.9	5.3	3300.7
Woody Understory					
Average Seed Mass (mg)	48.2	77.4	19.8	5.6	385.6
Woody Ground Layer					
Average Seed Mass (mg)	39.8	66.2	20.0	6.2	345.8
Herbaceous Ground Layer					
Average Seed Mass (mg)	3.5	2.3	0.7	10.5	2.6

A.69. Descriptive statistics of the relative abundance of average SLA in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of Average SLA in restored and unrestored plots. Average SLA of a community was calculated using community weighted means (CWM), which used species abundance and average SLA for each species.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy					
Average Maximum Plant Height (m)	26.9	5.6	26.8	17.2	38.4
Woody Understory					
Average Maximum Plant Height (m)	25.9	5.4	25.1	17.8	44.6
Woody Ground Layer					
Average Maximum Plant Height (m)	25.9	6.043	25.1	17.8	44.6
	Unrestored				
Canopy					
Average Maximum Plant Height (m)	23.4	5.3	23.0	12.1	33.1
Woody Understory					
Average Maximum Plant Height (m)	24.7	4.4	23.7	17.8	33.7
Woody Ground Layer					
Average Maximum Plant Height (m)	23.3	5.5	22.4	14.8	36.2

A.70. Descriptive statistics of the relative abundance of average maximum tree height in forest stratum communities of restored (n=30) and unrestored (n=30) plots. Table includes mean, standard deviation, median, minimum value, and maximum value of average maximum tree height in restored and unrestored plots. Average maximum tree height of a community was calculated using community weighted means (CWM), which used species abundance and average maximum tree height for each species.

	Restored				
	Mean	**SD**	**Median**	**Min**	**Max**
Canopy					
Average SLA (mm²/mg)	24.7	4.9	25.6	10.2	35.5
Woody Understory					
Average SLA (mm²/mg)	26.2	4.6	26.6	18.4	40.2
Woody Ground Layer					
Average SLA (mm²/mg)	27.9	9.21	26.0	11.8	45.1
Herbaceous Ground Layer					
Average SLA (mm²/mg)	42.7	6.9	42.9	25.0	54.1
	Unrestored				
Canopy					
Average SLA (mm²/mg)	23.7	6.9	25.4	6.6	32.3
Woody Understory					
Average SLA (mm²/mg)	24.1	1.1	23.8	22.7	27.1
Woody Ground Layer					
Average SLA (mm²/mg)	28.3	5.4	26.6	22.7	41.0
Herbaceous Ground Layer					
Average SLA (mm²/mg)	44.5	7.2	47.7	27.6	52.3

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